The "Westminster" Series

TEXTILES

The "Westminster" Series

Uniform. Demy 8vo. Illustrated

The Manufacture of Paper. By R. W. Sindall, F.C.S. 8s. 6d. *net*

Timber. By J. R. Baterden, A.M.I.C.E. 7s. 6d. net.

Electric Lamps. By Maurice Solomon, A.C.G.I., A.M.I.E.E. 7s. 6d. *net*

Textiles and their Manufacture. By Aldred Barker, M.Sc., Technical College, Bradford.

The Precious Metals, comprising Gold, Silver, and Platinum. By Thomas K. Rose, D.Sc., of the Royal Mint. 7s. 6d. *net*

Decorative Glass Processes. By A. L. Duthie. 8s. 6d. *net*.

The Railway Locomotive. By Vaughan Pendred, late Editor of *The Engineer*. 7s. 6d. *net*

Town Gas for Lighting and Heating. By W. H. Y. Webber, C.E. 7s. 6d. *net*

Liquid and Gaseous Fuels, and the Part they play in Modern Power Production. By Professor Vivian B. Lewes, F.I.C., F.C.S., Professor of Chemistry, Royal Naval College, Greenwich. 7s. 6d. *net*

Electric Power and Traction. By F. H. Davies, A.M.I.E.E. 7s. 6d. *net*.

Coal. By James Tonge, M.I.M.E., F.G.S., etc. (Lecturer on Mining at Victoria University, Manchester). 7s. 6d. *net*

India-Rubber and its Manufacture, with Chapters on Gutta-Percha and Balata. By H. L. Terry, F.I.C., Assoc. Inst. M.M. 8s. 6d. *net*

The Book: Its History and Development. By Cyril Davenport, F.S.A. 7s. 6d. *net*.

Glass Manufacture. By Walter Rosenhain, Superintendent of the Department of Metallurgy in the National Physical Laboratory. 7s. 6d. *net*.

Patents, Trade Marks and Designs. By Kenneth R. Swan, B.A. (Oxon.), of the Inner Temple, Barrister-at-Law. 7s. 6d. *net*

Precious Stones. With a Chapter on Artificial Stones. By W. Goodchild, M.B., B.Ch. 7s. 6d. *net*

Electro-Metallurgy. By J. B. C. Kershaw, F.I.C. 7s. 6d. *net*.

Natural Sources of Power. By Robert S. Ball, B.Sc., A.M.I.C.E. 7s. 6d. *net*

Radio-Telegraphy. By C. C. F. Monckton, M.I.E.E. 7s. 6d. *net*.

The Chemistry of Building Materials. By Alan Munby, A.R.I.B.A. 7s. 6d. *net*.

Photography. By Alfred Watkins, Past President of the Photographic Convention. 7s. 6d. *net*

The Gas Engine. By W. J. Marshall and Capt. H. Riall Sankey, R.E. 12s. 6d. *net*

Soils and Manures. By J. Alan Murray, B.Sc. 8s. 6d. *net*

Wood Pulp. By C. F. Cross, E. J. Bevan and R. W. Sindall. 8s. 6d. *net*

Welding and Cutting Metals by the Aid of Gases or Electricity. By L. A. Groth. 8s. 6d. *net*.

General Foundry Practice. By William Roxburgh. 8s. 6d. *net*.

Commercial Paints and Painting. By A. S. Jennings. 7s. 6d. *net*.

TEXTILES

BY

A. F. BARKER, M.Sc.

WITH CHAPTERS ON

THE MERCERIZED AND ARTIFICIAL FIBRES, AND THE DYEING OF TEXTILE MATERIALS

BY W. M. GARDNER, M.SC., F.I.C.

SILK THROWING AND SPINNING

BY R. SNOW

THE COTTON INDUSTRY

BY W. H. COOK, M.I.MECH.E.

THE LINEN INDUSTRY

BY F. BRADBURY

(REVISED EDITION.)

CONSTABLE & COMPANY LIMITED

LONDON : BOMBAY : SYDNEY

1922

Printed in Great Britain.

PREFACE

In the following pages practically the whole range of textiles comes under review, with the exception of certain special branches, such as Trimmings, Hose-pipings, Linings, etc. It is hardly to be expected that such a wide field can be satisfactorily covered by one writer, however well he may have been trained and whatever may have been his opportunities of gaining practical experience and insight. Thus, although I alone am responsible for the bulk of the work, special chapters by recognised authorities have been introduced. Professor Gardner is responsible for the chapters on " The Mercerized and Artificial Fibres " and " Dyeing " ; Mr. R. Snow for the chapter on " Silk Throwing and Spinning " ; Mr. W. H. Cook for the chapter on " The Cotton Industry " ; and Professor Bradbury for the chapter on " The Linen Industry." That these chapters add much to the practical value of the treatise will at once be conceded.

The authors hope that this work may prove of value to those who require extensive but accurate information on the whole range of the Textile Industries ; that the

technicalities dealt with in the work will serve well practical man in his every-day difficulties; and finally the student desiring an all-round knowledge upon wh to soundly base his later special knowledge will here that which he seeks.

ALDRED F. BARKE

THE TECHNICAL COLLEGE, BRADFORD,
FEBRUARY 16TH, 1910.

PREFACE TO THE REVISED EDITION

SEVERAL reprints of this work in its original form have issued. It is now felt by the authors that although the little to change in order to bring the work thoroughly u date, yet certain additions are called for, and that in some cases a broader outlook may well be advocated.

With these additions and revisions incorporated, it is h that the work may prove as acceptable in the future as i proved in the past.

ALDRED F. BARKE

THE UNIVERSITY, LEEDS,
NOVEMBER 1ST, 1921.

CONTENTS

LIST OF ILLUSTRATIONS

TEXTILES

CHAPTER I

THE HISTORY OF THE TEXTILE INDUSTRIES; ALSO OF TEXTILE INVENTIONS AND INVENTORS

THE authentic history of the textile industries has been carried so far back into the past ages by the archæological discoveries of the last hundred years that an interesting account of the evolution of these industries could readily be compiled. Such an account, however, while of interest from an archæological and historical point of view, might not be of much practical value: it would almost certainly be diffuse where concentration and triteness were desirable, and, possibly, too brief in dealing with those periods when change multiplied change, causing a rapid and extensive evolution.

A sequential history of the development of the textile industries will here be preferable, although such will naturally sacrifice a certain amount of absolute accuracy to ensure a more perfect statement of the sequence of developments; perhaps even a sacrifice of actual historic order may at times be necessary to impress the real historic teaching involved. Not that in the following pages history is to be outraged and actualities suppressed or changed out of recognition; but rather that to gain all that history should teach a certain practical licence will be

taken in presentation of the subject, its justification being in the clearness and precision thereby gained.

Throwing back our minds to the time when our ancestors were emerging from the barbaric state, we can well picture to ourselves their earliest dress as the skins of slaughtered animals. As the human race was probably evolved from the torrid-temperate zone (in Central Asia), it is possible that some lighter form of wearing garment preceded the skins of animals for personal wear, But it seems very probable that the first idea of textures of real wearing value would be first thus suggested.

If any animal such as the sheep then existed, we can well imagine that the shearing of a fleece would suggest the matting together of fibres already favourably disposed for the formation of a continuous covering. Felt fabrics undoubtedly came early in the historic sequence; thus both garments and hats of felt were worn in Ancient Greece; while remains of felts can also be referred to a much earlier period. But wool being the only fibre which truly "felts," the felt industry naturally cannot go further back than to the discovery of the felting property of wool.

Wool could only be converted into a woven fabric by being spun into a "fibre-thread." Now prior to the spinning of "fibre-threads"—or yarns as we now term them—the art of interweaving rushes and other fibres or bundles of fibres of long length was undoubtedly practised, so that the art of weaving evidently preceded that of spinning in the natural evolution. Again, it is probable that the art of weaving preceded the art of felting, as it is a debateable point whether the art of felting preceded the art of spinning.

The spinning and weaving of fibre-threads or yarns are

obviously most delicate processes in comparison with rush and coarse fibre weaving; but it is nevertheless true that as far back as the early Egyptian Dynasties a most refined art of weaving was practised, so much so that to-day Egyptian mummy cloths of a gauze structure are found worthy of reproduction.

Turning to the conditions under which the arts of spinning and weaving would be practised in the early days of our civilization, we come across traditional industries retained in the family. It is more than probable that in some of the ancient civilizations the textile industries became more than family concerns, but so far as we are concerned the textile industry may be regarded as essentially a family industry until the home industries—developed from family industries — appeared about the commencement of the eighteenth century. This does not discount the "Trade Guilds" which flourished in many centres of industry, such being based as much upon the family as upon a more highly organized form of the industry.

So long as all industries were distributed over the country it is evident that there would neither be the need nor the incentive for large production: the incentive would rather be towards the production of better fabrics and more artistic effects. Hence the marvellous beauty of many of the fabrics which came down to us from a very early date. And it is interesting and instructive to note that up to the nineteenth century attempts to introduce machines to facilitate production invariably claimed small consideration, while machines to facilitate the production of elaborate styles were certainly more than welcome. The "draw-loom" was successfully introduced from China, but M. de Gennes'

power-loom failed; Jacquard looms were in use long before the power-loom was either invented or adopted by the trade. Thus the art of producing elaborate and beautiful textiles followed civilization from the East to Southern Europe and from Southern Europe northwards. Marked indications of this line of development are still evident in the present-day organization of our industries, as will be shown later.

With the disturbance of the balance of production by the going forth of Europe's, but more especially England's, sons as colonizers would come the pressing demand for the greater production of certain commodities, of which cloth would be one. This would tend to break up the family traditions and to develop an industry organized on a larger scale, resulting in what might fairly be termed "specialized production" or organized home industries. Bringing groups of artisans together could not fail to stimulate industry and inventiveness, which in this case would naturally run on the lines of increased production. Now the Continent would naturally have shared in this evolution had it been tranquil and comparatively undisturbed as was England. But the Napoleonic wars were such a constant source of ferment on the Continent that tranquil, undisturbed England reaped nearly all the direct benefits of the very rapid evolution dating from this period.

About 1750 there commenced a natural evolution of the textile industries—spinning and weaving—the final result of which was to leave England for a long period of years practically supreme as a manufacturing country.

Prior to this evolution two kinds of spinning wheels were in use, one of which might be termed the "long-fibre wheel" and the other the "short-fibre wheel." In the case of the long-fibre wheel (Fig. 9) a sliver of long fibres was

practically made up from the raw material to the right thickness by hand and then twisted and wound on to the bobbin at the same time by the action of the flyer and bobbin. The introduction of this wheel had increased the product about threefold, in comparison with the distaff and spindle. The attempt to use a double-spindle wheel no doubt suggested at an early date the more perfect and automatic production of slivers which might then be spun in greater numbers by hand. Thus in 1748 Lewis Paul developed the idea of drafting rollers. That he probably got the idea from seeing rollers used for elongating or working metal is indicated by the fact that it was thought possible that one pair of rollers would do all that was necessary, elongation of the sliver presumably being thought to vary with the pressure exerted. This mistake was soon rectified, and two or more pairs of rollers adopted. Richard Arkwright now came upon the scene and, linking up the drafting rollers of Lewis Paul with the long-fibre spinning wheel, made it possible to control more than one or two spindles at the same time. Arkwright then linked up the water wheel to this machine and thus evolved what is known as the "water-frame," yielding a type of yarn known even to-day by the term "water-twist."

It is probable that the "short-fibre wheel" was employed in the spinning of wool and of cotton—cotton was then a comparatively small industry[1]—both of which were woven

[1] Year 1701:

Cotton Exports	£23,253
Woollen Exports	£2,000,000

Year 1833:

Cotton Exports	£18,486,400
Woollen Exports	£6,539,731

into fabrics known as Lancashire woollens. Spindle-draft, as distinct from roller-draft in Arkwright's machine, was here employed, the reduction of a thick carded sliver into a comparatively thin thread being accomplished by mere extension, by the movement of the hand away from the spindle point, with the aid of a little twist; then upon the completion of the drafting the necessary twist was put into the thread. The process was intermittent, as winding on to the bobbin followed this drafting and twisting. The idea of working more than one spindle would here be more difficult of realization than in the case of the flyer, as the cycle of operations was much more complex. Improvements in the preparation of the slivers would here also forward the multiplication of the spinning spindles. Thus Hargreaves invented the "jenny," which was simply a multiplication of the spindles to be worked by hand, the action being really an exact copy of the mechanical operation of spinning on the "short-fibre wheel." This was soon followed by the "slubbing-billy," in which the position of spinning spindles and the slubbings were reversed, as in the mule of to-day. The "billy" was gradually developed by such men as Kelly, Kennedy, Eaton, and many others, into the hand-mule, and finally the hand-mule was successfully converted into the self-acting mule by Richard Roberts in 1830.

Much has been made of the invention of the "mule" by Crompton. But the truth is our ideas here need considerable revision. Crompton's idea of combining the drafting rollers of Arkwright's water-frame with the spindle-draft of Hargreaves' "jenny" was simply a "happy thought." Certainly this happy thought was combined

with a certain amount of resolution and skill in putting the idea into practice, but it should be noted that the woollen "mule" of to-day is not Crompton's mule at all, and in fact is not a "mule," but a "pure-bred," and all the really ingenious mechanism on both woollen, cotton, and worsted mules is not due to Crompton, but to the men previously mentioned. It is further interesting to note that most of the complex mechanisms combined in the mule were known to spinners and would-be inventors prior to Roberts taking the mule in hand, but owing to their lack of power of sequential integrating thought they all failed in devising a successful machine. It was Roberts who combined the ideas presented to him into a harmonious whole and gave to the world one of the most wonderful and ingenious machines which has ever been invented.

It will readily be imagined that the improvements in spinning just mentioned naturally resulted in a marked multiplication of yarn production. Curious to relate, however, there does not appear to have been over-production of yarn, but rather under-production of cloth. It is said of the hand-loom weavers of this period that they went about with £5 sewn in their hats, so remunerative was their art. The invention of Kay's "fly-shuttle" in 1738—an invention be it noted which could only affect production, not quality nor elaborateness of the resultant fabric—had been followed by others which brought the hand-loom up to the perfection of to-day. The word "witch"—applied to the shedding mechanism known to-day as the "dobby"—carries with it an indication of the way in which some of these innovations were regarded. The placing of two or more shuttles in movable planes or

shuttle-boxes, any of which could be brought into line with the picking plane, was possibly introduced in more places than one quite independently, while "permanent back-rests," "setting-up" and "letting-off" motions had developed, so far as might be, the possibilities of the hand-loom from the production point of view.

And here it is well to realize definitely that there were three distinct phases in the development of the textile industries. In the Middle Ages we note these industries as distributed, laborious and, comparatively speaking, unproductive vocations. In the eighteenth century these distributed industries were becoming more concentrated and, more important still, were developing almost all the well-known methods of spinning and weaving employed to-day. Then came the nineteenth century, with its applied power—in some cases the application of power leading to the development of a machine, and in other cases the development of a machine leading to a better control and application of power. It should here be noted that, although the cotton trade was introduced into this country from India and the East, and although there was legislation against the use of cotton and in favour of wool prior to the mechanical era, still this trade was necessarily so restricted that it was not until the possibilities of the steam-engine and power machines were realized that the cotton industry took on a really serious and substantial development.

It is interesting to note that power was practically applied to the spinning frame earlier than to the loom. Arkwright's "water-frame" was successfully run shortly after 1769, while no practical power-loom was running until about 1813. By the middle of the nineteenth century hand-spinning was fast disappearing from all the manufacturing districts, but hand-

weaving is even still continued in the twentieth century. Arkwright's "water-frame" was most easily rendered automatic; the spinning-jenny or "mule" up to a certain point was soon rendered automatic, but the completion of the necessarily complex cycle of operations automatically was not accomplished until Roberts faced the problem in 1825. The cycle of operations involved in weaving being more complicated than the "water-frame" cycle, but less complicated than the "mule" cycle, would naturally have come in between but for the difficulties in obtaining a steady drive. Dr. Cartwright's first attempt at a power-loom was made without the slightest reference to a hand-loom and proved a failure. His second attempt was based perhaps too much upon the hand-loom, but may be regarded as having been fairly successful. It is well to fully realize that, while the introduction of water-power facilitated spinning, it did not facilitate weaving to nearly the same extent; simply because for weaving a really steady drive to ensure steady picking is necessary, and this was probably not by any means attained to in the early days of water-power driving. Later, when steam power was applied, marked improvements in steadiness were rapidly developed, with the result that practically most movements involved in ordinary spinning and weaving could be accomplished automatically from 1830 onwards. Then came the exodus from the country districts and the centralization of industries on or near to the coalfields. Thus it is interesting to note that prior to England becoming a manufacturing country the wool of England met the skill of Southern Europe in Flanders. Later a distributed industry is to be noted in England, the industry generally following the line of supply of the raw material. Still later the coal-power of Yorkshire

meets the wool production of Yorkshire at Bradford, and the coal-power of England the cotton of America in Lancashire.

Attention was now turned to the more perfect preparation of the slivers of wool, cotton, flax, etc., for the subsequent spinning process. Hand-cards were early displaced by the roller hand-card, and this in turn developed into the "flat-card" and later the "revolving flat-card." The development of the card, however, was more of an engineering problem than a problem in mechanism, the style of build and accuracy of setting being the real difficulties. There is an exception to this, however, in the case of the woollen condenser. Originally cardings were left exceedingly thick and unwieldy, having to be drawn out into slubbings and then into slivers, finally to be spun on the wheel or jenny. The first improvement was the dividing of the card-clothing on the last doffer into strips of 6 inches to 8 inches wide across the doffer, so that from the circumference of, say, a 24-inch doffer 10 or 12 slubbings just the width of the card—each say 27 inches to 36 inches long—would be stripped, these strippings being piecened up on the apron of the slubbing-billy by boys and girls called "pieceners." Then what was called a "piecening machine" was added, which, taking charge of these slubbings, each as long as the doffer was wide, stripped from the doffer, joined or placed them into continuous slivers, which were wound on to a spindle or bobbin, and placed later on the slubbing-billy.[1]

Some time after the introduction of the piecening machine the "condenser" made its appearance. In this the last doffer or doffers were clothed concentrically with rings of card-clothing, so that the slivers were stripped continuously from the doffer, and were practically endless as compared with the 36-inch slubbings stripped from across the doffer of the

[1] See "Journal of the Textile Institute," 1912.

old card. In the latest form of condenser the wool is stripped from the last doffer in a continuous film, and then broken up into 60 to 140 filaments by means of narrow straps or steel bands. One wonders why the idea of the ring-condenser was not sooner thought of and why it should have been so frequently tried and discarded. A little thought, however, soon clears up this point. It may be taken that wool fibres take up a more or less concentric position on the card. If this be so, then stripping the wool off the doffer in the old method would result in the fibres taking a concentric position in the thread, while in the case of the condenser they would take up a longitudinal position in the thread. This, no doubt, seriously affected the subsequent spinning, weaving, and finishing properties; in fact, it is frequently stated that no fabrics equal to those made from yarn spun from the old piecening slubbings are to-day produced. Possibly the realization of this difference suggested the idea of preparing wool for combing by previously carding it. This was first carried into practice about 1847 and is to-day being largely applied even in the case of wools 8 inches to 10 inches long.

The cycle of movements in hand-combing being more complicated than the cycle of movements in carding, automatic combing naturally developed much later than automatic carding. The operations of lashing on, combing, drawing off, and the removal of "backings," of "milkings," and of "noil" were necessarily very complicated, and it was largely by the elimination of certain of these that mechanical combing was made a success. As with most other machines, the first mechanical attempts were simply imitations of the hand process. Dr. Cartwright from 1789 to 1792 brought out two forms of mechanical combs which after many vicissitudes

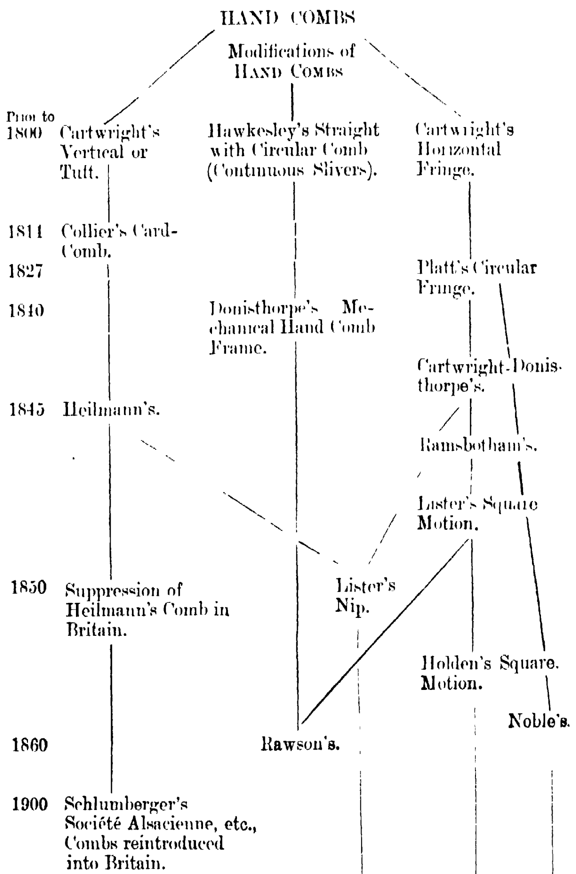
were laid aside for many years until they both again emerged—the upright circle comb as Heilmann's comb, the horizontal circle comb in its most perfect mechanical form as Noble's comb. It should be noted, however, that it is Lord Masham (then Mr. S. C. Lister) to whom credit must be given for the creation of a practical wool comb: without his "driving-force" there can be no doubt but that the evolution of the wool comb would have been long delayed. As with spinning so with combing: the preparatory processes were of marked importance. Without the preparing or gill-box and the card, mechanical combing would to-day be at least very imperfect if at all possible. The "Genesis of the Wool Comb" is given in List I.

We have now dealt with the evolution of all the important textile mechanisms with the exception of the ring and cap frames, which may finally be briefly touched on.

Labour, especially male labour, being very scarce in the United States, difficulties were encountered in working the heavy mules or mule-jennies needed for the production of certain yarns. Again, the questions of speed of machine and production would no doubt claim attention. Thus in 1832 the ring-frame (Fig. 15) was invented, this being readily controlled by female labour and eminently suited to the spinning of certain useful cotton counts.

Other ideas of frame spinning had naturally been tried in the States. The Danforth or cap spindle, coming to Lancashire about 1825, was condemned for cotton, but being introduced into Yorkshire was adopted as the system *par excellence* for the spinning of fine Botany yarns. It is curious to relate that the first trial of this spindle in Yorkshire was made at a very slow speed "to give it a chance." The result

LIST I.—THE GENESIS OF THE MACHINE WOOL COMB.



List II.—Development of the Factory System.

Development of Mechanical Methods of Manufacture.	Development of Organization culminating in the Factory System.	Developments of Markets.
FIRST PERIOD.		
Distaff. Hand Cards. Hand Combs. Jersey Wheel. Flax Wheel. Hand Loom.	1545. Principle of Interest admitted. 16th Century. Silk Mills at Bologna. 1609. Bank of Amsterdam.	*Prior to* 1750. Virginia. West Indies. Hudson Bay Territory. Newfoundland. Gibraltar.
SECOND PERIOD.		
1589. William Lee . Stocking Frame. 1650. M. de Gennes . Power Loom. 1738. John Kay . . Fly Shuttle. Robert Kay . Drop Box. 1738. Lewis Paul, John Wyatt . Drawing by Rollers (ass power). 1748. Lewis Paul . Roller Card. 1750. M. Vaucanson . Swivel Loom. 1758-59. J. Strutt . Rib Hosiery Frame. 1764. Jas. Hargreaves . Spinning Jenny. 1769. R. Arkwright . Water Frame. 1772. John Lees . . Improved Card. 1779. S. Crompton . Mule.	*Up to* 1690. *Entirely Domestic.* 1610. Water-power suggested for spinning. 17th Century. Child Labour (six years). German Spinning Schools (girls). 1631. East India Co. imported fine calicoes into this country. 1641. Introduction of the cotton fibre into this country for industrial purposes. 1670. Introduction of fine Indian muslins into this country. *Up to* 1730. *Combined Home, Warehouse and Mill.* 1718. Lombe's Silk Mill. (King's influence and power.)	*Prior to* 1800. India. Canada. Florida. Australia. Ceylon.

			Up to 1780.	*Development of Domestic Industries. From Pack Horses to Waggons. Turnpike Roads. Riders of Orders.*	
			1738.	Wyatt and Paul's Mill driven by two asses.	
			1750 to 1757.	First Woollen Mill in Workhouse.	
			1757.	Water-power fully employed.	
			1774.	Cotton trade recognised as a lawful industry.	
			After 1780.	*Partners in London and on Continent. Agents, Factors and Brokers established. Market Days.*	
			THIRD PERIOD.		
1785.	E. Cartwright .	First Power Loom.	1784.	First Worsted Factory.	*Prior to* 1850.
1789.	,, .	Wool Comb.	1786.	Cartwright employs steam-engine.	Cape Colony.
1790.	,, .	Wool Comb, etc.	1818.	The slubbing frame first brought into worsted use.	Natal.
1792.	,, .	Wool Comb, etc.			New Zealand.
1797.	,, .	Steam-engine.	1822.	A carpet mill and 100 hair-seating looms at work in Sheffield.	British Guiana.
1789.	Jas. Watt .	Steam-engine.			Tasmania.
1790.	Kelly .	Power Mule.	1834.	Cotton warps introduced into Bradford trade.	Mauritius.
	Johnson .	Warps Dressing Frame			Malta.
1804.	J. M. Jacquard .	Jacquard Loom	1851.	Whytock's invention of the tapestry, or warp printed carpet.	*After* 1850.
1813.	Horrocks .	Power Loom.			Opening up of China.
1823 to 1830.	Heilmann, Jordam, Risler and Dixon .	Power Looms, Comb and Mule.	1905-6.	Great demand for woollen khaki—Russo Japanese War.	Japan.
	Whitehead .	Picening Machine.	1914.	Bad Trade. European War.	Africa, etc.
1856.	Hattersley .	First Revolving Box Loom.	1916.	British wool clip commandeered	1918. Phenomenal rise in price of wool.
1868.	,, ,, .	First Revolving Skip Box Loom.	1918 to 1919	Gradual relinquishing of Government control.	1919. Phenomenal fall in price of wool.
1884.	Moser .	Invention of Moser Raising Gig.			

was that the yarn could be jerked off the bobbin or spool. It was only when the bobbin was speeded up from 2,000 to 5,000 revolutions per minute that the possibilities of this spindle were fully appreciated.

From 1850 onwards with the exception of the electric Jacquard and certain most interesting methods of pile weaving —no marked advances in the general form of the machinery employed in the textile industries are to be noted. Nevertheless, the improvements in details have been many and in some cases of surprising merit.

The development of pile weaving and of pile weaving machinery may briefly be summed up as follows: The printed warp pile fabric was introduced by Mr. R. Whytock about 1832. This was followed by the Chenille Axminster—in which the colours were woven in—about 1839. From 1844 to 1850 the power wiring loom was developed in the United States and introduced into Great Britain. From 1856 to 1867 the power "tufting" or Axminster loom was developed, and finally, in 1878, Lord Masham succeeded in weaving two pile fabrics face to face, the pile stretching between an under and upper ground texture being severed in the loom by a knife which traverses from side to side with this object. From 1890 to 1910 the chief innovations have had reference to the cutting of weft-pile fabrics in the loom, the introduction of the looping or cutting wires through the reed, thus doing away with the necessity for any wiring mechanism, and certain marked improvements in the mechanism for producing Chenille Axminster fabrics.

* * * * *

Along with the developments outlined in the foregoing pages came the factory system. This system was no doubt evolved

by the disturbance of the balance of trade due to colonization and the various inventions noted. One thing reacted upon another, production increased production, spindle stimulated loom and loom spindle, until eventually a terrible strain was put upon those actually engaged in the factory, and in many cases humanity was sacrificed on the altar of increased production, most awful conditions prevailing. Slowly, however, the position of the worker has been improved both by direct and indirect legislation. Foreign competition has no doubt retarded still further improvements being carried into effect; but the *rapprochement* of nations due to increased facilities for communication must inevitably lead to a levelling up and to labour ultimately receiving due recognition both with respect to the conditions under which work is done and the pecuniary benefits derived from such work. Since the War this movement has been most markedly in evidence, even the Eastern nations agreeing to an eight- or nine-hour day. In Europe and America the status of the worker is being still further improved by means of the Whitley Works' Councils, by welfare work, by scientific management and by profit-sharing schemes. These and other similar developments, when rightly introduced into the factory, tend to lift the whole tone of the textile industries.

In List II.,[1] the concomitant early developments of Mechanical Methods of Manufacture, Organization of the Industry and of Markets, are given.

[1] NOTE.—This list was given in a different form in the article on "Wool Combing" appearing in "Technics" for August, 1904.

CHAPTER II

THE WOOL, SILK, COTTON, FLAX, ETC., GROWING INDUSTRIES

THE sources of supply of raw materials must always claim the careful attention of spinners and manufacturers, even if they have not to deal with the material at first hand. It may be questionable if all the fluctuations in price of cotton, wool, etc., can be accurately gauged by the most careful study of the economic conditions of the supply; but of this we may be sure, that a sound knowledge of the conditions of production and consumption will in a large percentage of cases enable the spinner or manufacturer to correctly judge the situation and thus avoid mistakes which otherwise would most surely be made. We must not forget that the successful man is he who makes the fewest mistakes!

About a hundred years ago most wonderful advances were being made in both wool and cotton growing. The development of the Continental merino wool trade, followed by the still more remarkable development of the Colonial wool trade, and later by the development of the South American wool trade—these and other minor but important influences have resulted in changes of momentous issue. Cotton much earlier than wool seems to have felt the coming revolution, becoming acclimatized or being further developed in the United States of America, the East Indies, Peru, and later in Egypt. It is further interesting

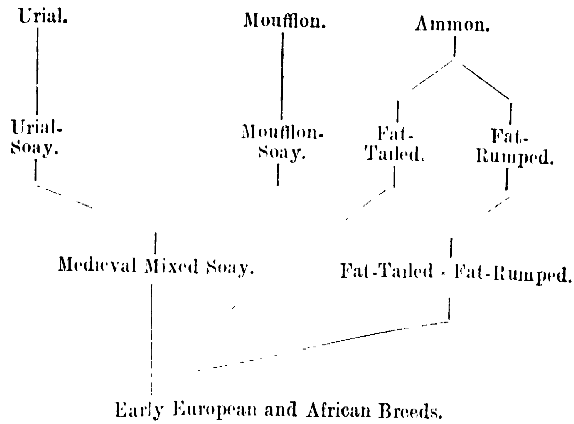
to note that of late there has been a most decided unrest in cotton producing and consuming circles, resulting in the institution of the British Colonial Cotton Growing Association, which, if somewhat languishing before the war, is now threatening to again revolutionize the cotton markets. Silk also has made a remarkable advance, owing to the discovery of the possibilities of reeling certain wild silk cocoons and therefrom making a good quality of net silk. None the less remarkable have been the developments in the waste and artificial silk industries. Flax has never markedly changed its centre of gravity—at least so far as production is concerned—this no doubt being due to its being one of the fibres most easily spun by hand, and hence having been in general use prior to the industrial era. Its cultivation was much more distributed up to about 1870, but the chief centres of flax production, Ireland, Russia, Germany, Holland, and Belgium, are all old established. Other vegetable fibres, such as China grass, Phormium Tenax, etc., have from time to time appeared, and it does seem as if at last China grass has come to stay; especially is this remark true for the mantling industry, which during and since the war has made a marked development. The following sections, which must only be regarded as notes, give a broad outline of the development of the respective industries. Perhaps such notes possess a value which is not diminished but rather accentuated through their very brevity and triteness.

The Wool Growing Industry.—The sheep as we have it to-day is said to be a development, through years and years of selection and acclimatization, of somewhat rough-haired animals originally reared on the central plains of Asia. The evolution of the sheep was no doubt dependent upon the

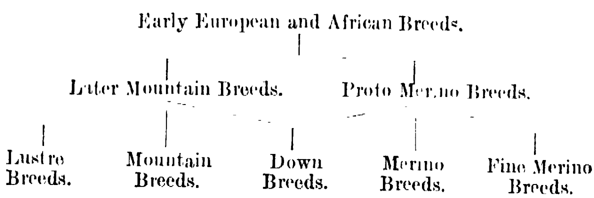
advancement in civilization of the peoples ultimately destined to spread not only over Asia, but Europe and Northern Africa also. It seems quite probable that the Arabs following the north coast of Africa into Spain took the partially developed sheep with them and by their well-known skill and carefulness, aided by climatic conditions, ultimately produced the Spanish merino, to which the merino flocks of the world owe their origin either directly or indirectly. At the same time that this evolution was taking place, the Asiatic tribes who struck northward across the central plains of Europe possibly also took with them the partially developed sheep which ultimately arrived in England. The evolution of our domestic sheep has recently been brought much more into evidence through the researches of Professor J. Cossar Ewart, F.R.S., of Edinburgh University. Thus the short-tailed sheep derived from the Urial, Moufflon and primitive herds, as shown in List III., have come into Britain, and, in fact, seem to have spread over the whole of Europe, and are still to be found in their pure form in the little island of Soay, to the north-west of Scotland. The fat-tailed and fat-rumped sheep have also come to these islands and, being crossed with the Soays, have finally yielded our normal domestic sheep with its long tail.

In List IV. the derivation of our present-day domestic sheep from the mountain and merino types is illustrated, this list forming a most excellent key for the study of the present-day breeds of sheep. Professor Ewart's researches have led to the suggestion that the original sheep was double-coated, *i.e.*, it carried an overcoat of long, strong hair and an undercoat of fine wool. It is further suggested that, in the case of the merino, the long, strong hair has been bred out and the fine wool developed, while in other cases the fine wool has

LIST III.



LIST IV.

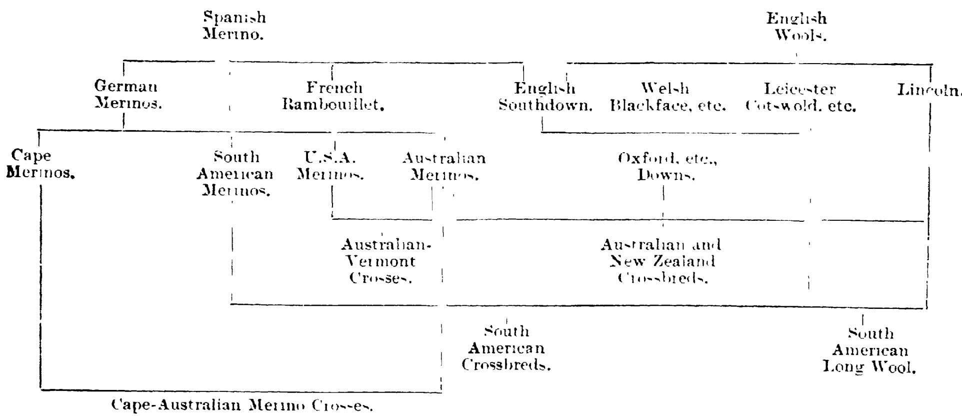


been bred out and the strong hair developed. The Scotch Blackface sheep to this day carries a strong hair of about $\frac{1}{400}$ inch in diameter and a fine wool of about $\frac{1}{700}$ to $\frac{1}{1000}$ inch diameter.

In List V. the derivation of the merinos and the merino crosses—termed crossbreds—are shown.

It seems more than probable that the original progenitor of the sheep was black or brown, and it is interesting to note

LIST V.



Note.—Merino breeds are placed on the left, English breeds on the right, and Crossbreds in the centre.
•So far as may be the history of each breed is shown vertically. Thus the French Rambouillet was probably the origin of the Vermont Merino, while the pure Spanish Merino was possibly transferred to the South American Colonies. Again, the Leicester breed is probably the most representative of cultivated English wools, etc.

that there are continual reversions to this colour in some of our whitest and finest breeds—Wensleydales, for example. So much has this tendency marked itself in certain parts of Australia that flocks of brown or black sheep have been established. The change in colour of the average sheep from brown to white is said to have been due to the custom of paying for shepherding with the white lambs dropped. This naturally led to the shepherds promoting the breeding of white sheep—as told with reference to Jacob in the Bible—with the final result that when the attempt was seriously made to breed pure white sheep success was soon achieved. Perhaps this matter is better approached in the light of Mendelian research, the white sheep usually being dominant and the black sheep recessive. The Cambridge University School of Agriculture and Wye Agricultural College have obtained some remarkable results in sheep-breeding on Mendelian lines, incidentally illustrating the Australian saying, "Three generations to find a breed, twenty generations to fix it."

It is reasonable to suppose that the sheep as a supplier of wool and mutton, was very widely distributed, and that the small quantities of wool produced would be spun and woven locally until some change upset this distributed equilibrium. So far as we can tell, the first change was due to the developed skill of the Continental workers, probably coming down the Rhine Valley and finally settling in Flanders. At least we know that the skill of the Flemish spinners and weavers was largely instrumental in creating England as a wool-growing country. The direct endeavours of several of the English monarchs coupled with Continental wars and persecutions ultimately resulted in the establishment of spinning and

weaving industries in England along with wool growing. Nevertheless the centralization of industry was only partial until, as already pointed out, our colonization of new worlds, Continental wars, certain mechanical inventions, and the application of water and steam-power gave rise to the factory system, which in its turn reacted upon the raw material producers and ultimately resulted in the development of the Cape, Australia, New Zealand, South America, the East Indies, etc., as the great wool-producing centres, although England still holds its own for its specially useful types of sheep. List II. gives an idea of how these markets developed and at the same time affected the production of wool in the older wool-growing districts.

It will be noticed from these lists that the most marked development of the Botany wool trade took place between 1850 and 1880, coinciding with the development of combing machinery capable of dealing with fine short wools, and with the invention and development of the self-acting woollen mule. In fact these lists conclusively prove that the development of the growing of fine wools was largely dependent upon the invention of machines with which to work them: thus the wool comb and the self-acting mule were really the deciding factors. Of course woollen yarn had previously been spun on the "billy" and "jenny," and Botany wool had been combed by hand, but these being all hand processes were the natural but very marked limitations, and it was only when these limitations were removed that the most noteworthy advance was made—just as the development of these improved hand methods had caused a marked rise in wool production fifty to seventy years previously.

It was the wonderful direct influence of the Australian

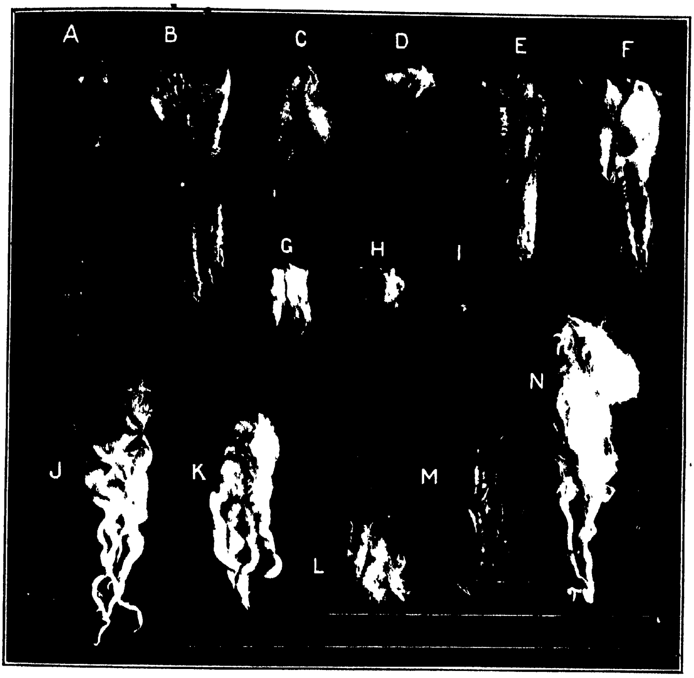


FIG. 1.—Wools and Hairs (the horizontal divisions = 1 inch). A, Lincoln; B, Kent; C, Shropshire; D, Australian Crossbred (46's); E, New Zealand Crossbred (46's); F, Buenos Ayres Crossbred (46's); G, Australian Merino (70's); H, Buenos Ayres Merino (60's); I, Cape Merino (64's); J, Turkey Mohair; K, Cape Mohair; L, Cashmere; M, Camel's Hair, N, White Alpaca. *Note.*—The presence or absence of grease on these natural wool staples has affected the colour.

climate upon the fleeces which first called attention to Australia as a possible fine wool-growing centre. The climatic conditions, however, were not the same all over the island continent, so that later developments have taken the line of

heavier sheep of a greater value from a "muttoh" point of view, with a consequent development in crossbred wool growing. When wool was down at a very low price in 1901-2, "mutton" became the chief factor in the case of all lands carrying crossbred or heavy sheep—as was also the case during these years in England. A large part of Australia, however, is only fitted for carrying the lighter merino breed, and thus will never be markedly affected by the frozen mutton trade. The great drought of 1897-8 and later Australian droughts of a serious character, in conjunction with a tendency to breed fewer sheep in other countries—South America and Canada, for example—have suggested the possibility of a world shortage of wool. For the time being the wool market is congested (October, 1920), but when this passes away it does seem possible that the newly developing sheep-breeding districts in Peru, India, China and Japan may make useful and necessary contributions to the wool requirements of the world.

New Zealand, having a climate more akin to that of England, has always produced wools of the crossbred type, merino sheep being bred in some few districts only.

The Cape has been a wool-producing country longer than Australia, but climatically is apparently not so suited to the production of wool of good type. Of late much has been done to improve Cape wools, and they are naturally more sought after, especially by the Germans, who seem to be specially capable of manipulating them.

Of recent years the country which has advanced most in wool production is South America. Originally a common sort of merino wool was grown, but now, owing to careful breeding and selection, both fine Botany and well-developed

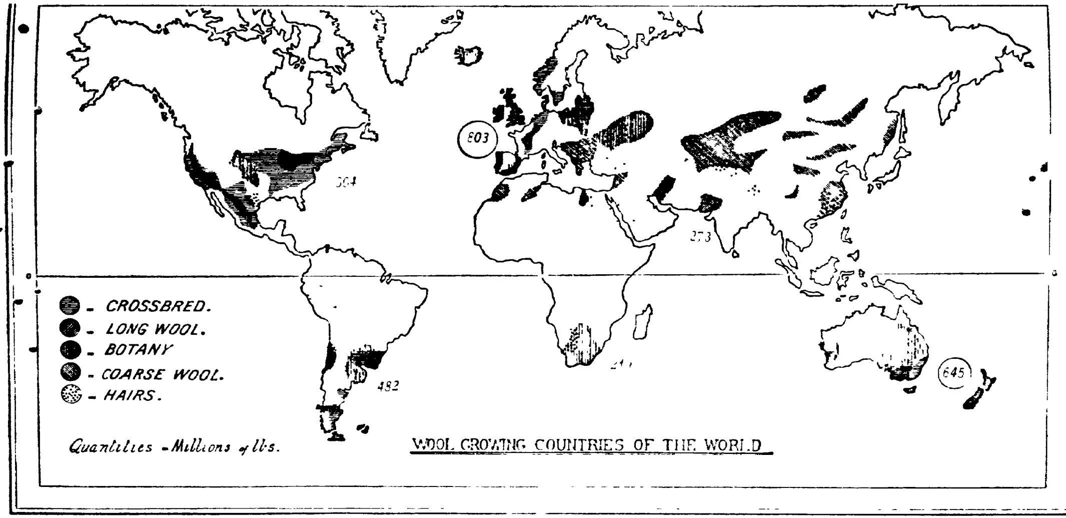


Fig. 2.

Wool Growing Countries of the World.

Wool Production, 1919

	lbs.
Australia	645,132,880
South America	482,640,707
North and Central America	304,223,000
Europe :—	
U K	121,200,043
Russia in Europe	320,000,000
France	75,000,000
Germany	25,600,000
Europe (contd.)—	
Italy	21,500,000
All other	240,500,000
Total Europe	803,400,043
Asia	273,146,000
Africa	219,919,000
World's Total	2,728,461,650

crossbred and even English wools are produced. The wool capabilities of the South American Continent are by no means exhausted, and it seems a pity that we English failed to realize the wonderful potentialities of a country likely in the near future to play such an important part in the world's history. It is principally to this country that the £1,000 Lincoln rams are continually being exported.

The United States of America very early attempted and succeeded in establishing flocks of sheep ranging from crossbreds to truly fine merinos, although, as already pointed out, they at first as colonists drew practically all their cloths from the mother country, and still take large quantities of the finer goods. That the United States is capable of producing a fine merino wool is proved from the use—rightly or wrongly—which has been made of the Vermont merino sheep in Australia. This use, however, has been made with the idea of producing a heavier fleece rather than a finer wool. America still buys English sheep and English wools, the importation of the sheep probably being necessary to correct the tendency to degenerate owing to climatic conditions. It is interesting to note that the United States now grows about half the wool needed by the manufacturers, and her total wool manufacturing trade closely rivals that of Great Britain.

Of the hairs manufactured into fabrics of various descriptions, Mohair, Alpaca, and Cashmere are the most important. Horsehair, Cow-hair, Rabbits' fur, etc., are used in small quantities only and for very special purposes. In List VI. the sources of the various animal fibres other than wool are indicated, and in List VIa. the variations in the camel representative in South America are graphically shown.

That mohair was used in England two to three hundred

years ago is evident from allusions to mohair fabrics made, for example, by Dryden. These fabrics, and later mohair yarns (hand spun), were no doubt imported from the emporiums of the East, and it was only about 1848 that supplies in quantity of the raw material commenced to come into this country. Various restrictions were at first placed upon the export of the hair, but now it is an established trade and very considerable in bulk. More stringent restrictions were placed

LIST VI.

Common Ancestor.

Goats. Camels. Sheep.

LIST VIA.

Huanaco.[1]

Vicuna. Alpaca. Llama.

Special Cross. Special Cross.

on the export of the Angora goat, but owing to a certain amount of vacillation flocks have been firmly established at the Cape and also bid fair to become established in California and Australia. Turkey mohair still maintains supremacy so far as quality and lustre are concerned, but Cape mohair, which, by the way, is clipped twice from the goat each year,

[1] This animal ranges South America from Peru to Patagonia. It is still open to doubt whether it should be regarded as the progenitor of Vicuna, Alpaca, and Llama, or whether all should be referred to a common ancestor.

now runs it very close. The Australian supplies are not yet of much moment, while the industries of the United States consume all grown in California.

Alpaca comes from the Peruvian sheep or goat. This hair, although used in various forms for centuries by the inhabitants of Peru, claimed no special attention in this country until Sir Titus Salt discovered it and produced his famous "alpacas." The fibre is long and silky and in some respects--notably softness- is superior to mohair. Most of the so-called "alpacas" sold to-day are actually made of mohair, for, curious to relate, while the supplies of mohair have quadrupled during the past fifty years, the supplies of alpaca have almost remained stationary, as all attempts to naturalize the sheep outside Peru have failed.

Cashmere is obtained from the Cashmere goat, being the under-hair which is protected from the weather by a long coarse over-hair, and in turn no doubt serves the purpose of keeping the goat warm. This material came into notice as a useful fibre from the wonderful cashmere shawls which are so remarkable for their softness and fineness. The supplies of this material are in the hands of a select few and it is used for very special purposes. Soft, fine Botany wool is, however, frequently sold in a manufactured state as "cashmere."

Camels' hair is obtained chiefly from China and Russia. The coarser kinds or hairs are used for such purposes as camels' hair belting, while the "noil" or short soft fibre is used for blending with wools to yield special effects. The combing of this fibre, as also of Iceland wool, is very interesting, the idea frequently being to comb away the long fibres, leaving the "noil"—usually the least valuable part of the material—as a soft-handling and exceedingly useful fibre.

Cow-hair, rabbits' fur, etc., are only used for very special

textures. Rabbits' fur, however, is used to a considerable extent in the felt trade. It is here interesting to note that the latest fibre introduced into the manufacturing world is the under-wool of the musk ox, the Canadian traveller, Mr. Stefansson, having forwarded a consignment of this to the University of Leeds. The fibre is softer than cashmere, and promises to be of marked value in the industry.

Before leaving the wool industry reference must be made to the remanufactured materials, which briefly are Noils, Mungo, Shoddy, and Extract. The idea of using over again materials which have already served for clothing must be very old. It was not until 1813, however, that the Yorkshire clothiers succeeded in tearing up hard wool rags and therefrom producing a material capable of being spun into a fair yarn, especially if blended with other better materials. The operations necessary for this "grinding-up," as it is technically termed (although in truth the operation more truly consists in a teasing out), are dusting, seaming, sorting (according to quality and colour), oiling, and grinding. Obviously hard-spinners' waste would be most difficult to reduce again to a fibre state, but machines are now made that will grind up at least anything of wool; cotton, however, is another matter. The terms mungo, shoddy, and extract refer to the original quality of the goods from which these materials are produced; mungo being produced from soft short wool goods, shoddy from longer and crisper wool goods, and extract from goods made of cotton and wool from which the cotton is removed by the "extracting" process, the remaining wool being then torn up into a fibrous mass.

To supply this trade large quantities of rags are imported into this country from the Continent, the Dewsbury and

Batley districts working up a very large proportion. Quite recently the Americans made a very determined attempt to get hold of this trade, sending representatives into the Dewsbury district. They have undoubtedly been successful, although they cannot yet treat these materials quite so efficiently as the Dewsbury men. Germany has also a remanufactured materials trade of considerable moment.[1]

The "noils" referred to above are the short fibres rejected from either English, Crossbred, or Botany wools, or Mohair, Alpaca, etc., during the combing operation. They cannot be considered as quite equal to the original material, although they are undoubtedly superior to mungo, shoddy, and extract: they may have lost a little of their elasticity, but their scale structure is not so much damaged, nor are they so much broken up.

Soft wastes (*i.e.*, wastes into which little or no twist has been inserted) and hard wastes (*i.e.*, wastes into which twist has been inserted), from worsted spinning rooms, are now both brought back to a perfect fibrous state by the Garnetting machine, and form some of the best materials used by the woollen manufacturer. In some few cases the larger of these wastes are actually recombed on the French comb.

All these materials are either used alone or, more frequently, blended with better or what one might term "carrying materials." Cotton and mungo, for example, often compose the blend for a cheap but effective yarn for the Leeds woollen trade.

The following tables, taken from the "Statistics of the Worsted and Woollen Trades," published by the Bradford Chamber of Commerce, give a bird's-eye view of the past and present constitution of the wool industry; similar particulars respecting the other industries are given in the special chapters devoted to them.

[1] The re-manufactured materials employed in Great Britain total up to about 240,000,000 lbs. per annum.

Estimate of the Wool Grown in the United Kingdom in 1914.

County.	Sheep and Lambs. 1913.	Weight per fleece.	Total weight.
		lbs	lbs
Lincoln	937,545	9½	8,906,677
Yorks.—East Riding	431,215	8	3,449,720
Nottingham	173,412	7½	1,300,590
Cornwall	356,067	7	2,492,469
Devon	797,003	7	5,579,021
Gloucester	292,119	7	2,044,833
Hampshire	293,143	4½	1,319,143
Oxford	185,067	6¾	1,249,201
Northampton	351,343	6¾	2,371,564
Rutland	79,667	7	557,669
Leicester	277,491	7	1,942,437
Warwick	220,858	7	1,544,006
Kent	864,241	7	6,049,477
Ireland	3,620,724	6	21,724,344
Somerset	400,929	7	2,806,503
Hereford	303,804	5¾	1,746,873
Worcester	126,678	5¾	718,398
Stafford	189,926	5¾	1,092,074
Shropshire	447,559	6	2,685,354
Huntingdon	67,146	6	402,876
Bedford	69,488	6	416,928
Berkshire	128,815	6	772,890
Buckingham	163,449	6	980,694
Cambridge	134,361	6	806,166
Herts.	72,976	6	437,856
Norfolk	401,698	6	2,410,198
Suffolk	288,800	5	1,414,000
Essex	184,168	4½	828,756
Surrey	47,495	4½	213,727
Middlesex	14,326	5	71,630
London	2,164	6	12,984
Sussex	379,181	4½	1,706,314
Wilts.	392,155	4½	1,764,697
Dorset	292,973	5	1,464,865
Scotland	6,801,126	5	34,005,630
Northumberland	1,089,474	6	6,536,844
Cumberland	587,271	6	3,523,626
Durham	229,378	6	1,376,268
Westmorland	398,684	6	2,392,104
Yorks.—North Riding	694,214	6	4,165,254
Yorks.—West Riding	638,267	6	3,829,602
Lancashire	315,476	6	1,892,856
Derby	129,895	6	779,370
Chester	80,510	4½	362,495
Monmouth	206,037	4½	927,166
Wales	3,393,848	3½	11,878,468
Sheep and Lambs in 1913	27,552,136		155,084,617
*Slaughtered	11,294,858 at 3		33,884,574
Net Clip of Wool in 1914			121,200,043

* The figures necessary for calculating the number of sheep slaughtered in Ireland are not available, but an estimate has been made on the assumption that flocks in Ireland will have decreased in the same proportions as flocks in Great Britain.

NOTE.—The sheep and lambs of 1918 produce the wool of 1919. The loss of wool on the slaughtered sheep, estimated at 3 lbs. per fleece, must, of course, be deducted from the total possible yield. The above figures are, as usual, exclusive of the Isle of Man and Channel Islands.

T.

ESTIMATE OF WOOL GROWN IN THE UNITED KINGDOM IN 1915 19.

	Lbs.
Net Clip of Wool in 1915 . . .	122,474,977
,, ,, 1916 . . .	124,408,224
,, ,, 1917 . . .	125,176,066
,, ,, 1918 . . .	119,736,277
,, ,, 1919* . .	115,658,564

* Eleven months.

The Silk Growing Industry.—At one time this industry was practically limited to China and Japan, in which countries the silkworm was rigorously guarded. Some missionaries, however, in the year 552 managed to bring some eggs to Constantinople, and eventually the industry was firmly established upon the north shores of the Mediterranean. Various attempts have been made to establish the industry elsewhere. Attempts, for instance, were made to acclimatize the worm in Ireland, and at the present moment a certain amount of success seems to be attained in Australia; but rival industries or the unskilfulness of the rearers seem to prevent the attainment of any success of practical value. The United States, perhaps, may be regarded as exceptional in this respect. Not only have they developed their own breeds, but they have established a most complete silk industry from the worm to the finished product.

The most remarkable development in the silk industry was brought about in 1877 by Lord Masham, who, after many failures, succeeded in producing cheaply and successfully utilizing a most useful silk yarn from waste silks—old cocoons, brushings from the outside of the cocoons, throwing waste, etc. This development naturally lead to the utilization of wild silk, as tons of these pierced or spoilt cocoons

Exports of British Wool (Sheep's and Lambs') from the United Kingdom.
In Thousands of Lbs.

Exported.	1911.	1912.	1913	1914.	1915	1916	1917.	1918.	1919
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
To Russia . .	5,985	4,623	4.161	5.967	1,126	1 407	688	—	168
,, Sweden . .	654	854	861	802	307	296	10	—	—
,, Germany .	5.966	6.891	8.051	2.901	—	—	—	—	—
,, Holland. .	1.229	1,762	1,386	1,608	578	1,493	425	—	936
,, Belgium .	591	524	680	629	—	—	—	—	1,451
,, France . .	1,230	1.393	614	1.548	898	444	378	1,129	1.394
,, Italy . .	1,702	1.802	983	798	1.357	769	257	895	—
,, United States.	10,464	25,235	8,689	20.768	22.554	3,146	2.287	—	12,042
,, Other Foreign Countries .	799	1,170	863	998	1.522	1.772	525	36	—
,, Canada . .	2.068	2.731	2,307	2,331	3.660	3.779	2.387	266	893
,, Other British Possessions.	88	150	56	108	—	8	31	7	—
Totals .	30,777	47,135	28,662	38.458	32.003	13.114	6.988	2.332	18,463

IMPORTS OF WOOL (SHEEP'S AND LAMBS') INTO THE UNITED KINGDOM.

IN THOUSANDS OF LBS.

Imported from	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Russia	2,856	9,673	7,144	3,909	—	212	—	—	1,325
Denmark	374	252	202	256	—	12	1	—	—
Iceland and Greenland	186	386	433	57	271	345	150	560	—
Germany	2,380	3,836	4,718	2,327	—	—	—	—	—
Holland	335	399	346	240	—	—	—	—	—
Belgium	3,215	4,382	3,088	2,733	—	—	—	—	198
France	22,545	29,450	24,493	18,873	229	3,808	232	—	663
Portugal	1,467	1,873	1,421	1,670	447	349	—	8	—
Spain	303	112	101	105	—	224	—	—	—
Italy	940	1,608	1,238	367	—	—	—	—	—
Austria-Hungary	138	195	53	—	—	—	—	—	—
Turkey	11,939	7,747	9,428	4,129	878	2,708	3,057	6,175	—
Egypt *	3,329	3,181	4,112	4,196	6,526	—	—	—	—
Morocco	382	269	293	316	148	13	—	5	—
Persia	450	380	1,865	1,038	1,304	1,607	13	—	—
China	2,983	1,854	2,316	1,278	1,156	419	161	184	—
United States	1,763	658	2,583	4,727	2,372	289	199	11	—

Peru	2,981	3,068	5,281	2,866	3,003	2,735	1,228	1,670	11,216
Chili	20,519	20,791	24,287	18,007	15,278	8,115	5,628	1,373	
Uruguay	5,621	9,614	9,658	1,729	1,123	879	1,871	470	1,013
Argentine Republic	50,139	56,252	55,456	45,907	60,968	31,782	31,920	6,249	22,123
Other Foreign Countries	143	186	456	577	748	530	394	699	—
Total from Foreign Countries	135,004	156,255	158,970	115,307	87,925	54,023	44,874	17,407	—
Egypt *	—	—	—	—	—	5,419	2,884	2,222	80,595
Cape of Good Hope	72,343	83,518	92,813	81,871	136,565	62,811	30,295	28,540	
Natal	29,510	37,081	40,411	39,792		27,261	14,271	2,731	
British East Indies	56,588	55,270	54,946	46,983	65,436	61,793	48,233	61,855	63,018
Australia	323,991	285,062	265,078	239,233	426,164	241,722	338,225	204,757	587,057
New Zealand	174,121	184,240	181,181	184,608	200,032	157,853	142,105	89,299	254,196
Canada	205	555	724	52	1	8	7	—	—
Falkland Islands	2,577	4,542	6,151	4,454	3,045	4,352	1,755	5,772	2,943
Other British Possessions	177	343	306	318	689	705	554	873	—
Total from British Possessions	659,511	650,601	641,611	597,311	838,455	564,924	578,379	396,047	—
TOTAL	794,515	806,856	800,581	712,618	926,680	618,947	623,233	413,054	1,042,399

* Now a British Possession.

COLONIAL AND FOREIGN WOOL (SHEEP'S AND LAMBS') RE-EXPORTED FROM THE UNITED KINGDOM.

IN THOUSANDS OF LBS.

Exported.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
To Russia . .	421	173	384	155	7,329	6,880	2.881	—	128
,, Sweden . .	255	329	378	286	533	821	6	172	—
,, Germany .	85,370	101,239	93,197	88,785	—	—	—	—	—
,, Holland. .	7.048	8 742	5.983	6,562	2.033	1,945	1,266	—	3.114
,, Belgium .	72.769	65,158	70.497	49,468	—	—	—	—	40,712
,, France . .	87,197	76,962	86.073	59.646	20.739	13,137	14.772	12.672	87,084
,, Switzerland .	3	27	1.298	758	520	2.255	352	—	—
,, Italy . .	1,576	227	925	807	8,858	4,222	8,409	7,528	4,999
,, Austria-Hungary	232	284	123	147	—	—	—	—	—
,, United States.	46.245	81,471	44,537	85,842	77,208	12,148	2.092	—	24,649
,, Mexico . .	189	247	119	—	—	—	—	—	—
,, Other Foreign Countries .	136	171	399	135	1,092	495	33	—	—
,, Canada . .	2,685	2,560	2,566	2,457	4,615	3,449	831	57,861	—
,, Other British Possessions.	32	87	7	30	6	20	10	9	—
Total .	304.208	337,675	306.480	295,078	122.933	45,372	30,652	20,440	167.062

IMPORTS OF MOHAIR INTO THE UNITED KINGDOM.

Year.	From Turkey.		From South Africa.	
	lbs	£	lbs	£
1909	10,803,206	679,207	19,443,656	831,383
1910	11,285,454	704,520	18,474,303	801,444
1911	6,533,624	404,318	18,712,068	806,775
1912	10 539,006	637,125	24,410,180	1,030,338
1913	10,402,360	641,069	18,523,197	912,112
1914	9,007,839	559,103	17,591,882	882,919
1915	—	—	14,186,028	729,956
1916	—	—	11,215,019	732,731
1917	—		3,514,605	282,980
1918	—	—	5,577,549	541,870
1919	—	—	19,260,647	2,144,041

IMPORTS OF ALPACA, VICUNA, AND LLAMA WOOL INTO THE UNITED KINGDOM.

Year	From Peru		From Chili	
	lbs	£	lbs	£
1909	4,837,858	265,067	432,085	21,649
1910	5,429,408	299,353	429,270	21,481
1911	5,019,542	271,800	355,063	20 310
1912	3,422,015	165,164	181,[illegible]95	10,078
1913	5,432,386	288,951	388,908	19,477
1914	4,295,190	225,653	199,247	11,464
1915	6,729 235	408,380	1,219,039	95,235
1916	5,372,416	362,862	486,485	36,998
1917	5,120,482	469,924	459,267	45,167
1918	6,479,782	1,378,394	555,234	128,859
1919	2,625,623	466,875	1,000,397	176,933

—supposed to be unworkable—were available. Thus was developed the remarkable trade known as the "spun silk trade." Curious to relate, however, the latest discovery is that many of these wild silk cocoons can be reeled, as will be further explained in Chapter XV. The supplies of wild silks are not yet exhausted, as news is just to hand of the

TOTAL EUROPEAN AND AMERICAN WOOL IMPORTS.

—	1910.	1911.	1912.	1913.
	Bales.	Bales.	Bales.	Bales.
Australasian .	2,411,000	2,524,000	2,463,000	2,296,000
Cape . . .	377,000	376,000	463,000	484,000
Total Colonial .	2,788,000	2,900,000	2,926,000	2,780,000
River Plate .	461,000	499,000	497,000	437,000
TOTAL. .	3,249,000	3,399,000	3,423,000	3,217,000

—	1914.	1915	1916.
	Bales	Bales	Bales.
Australasian .	2,322,000	1,978,000	1,781,000
Cape . . .	499,000	414,000	453,000
Total Colonial .	2,831,000	2,392,000	2,234,000
River Plate .	406,000	Unavailable	Unavailable
TOTAL. .	3,237,000	2,392,000	2,234,000

discovery of wonderful nests of cocoons in Africa (Congo State), arrangements for the exploitation of which are only just being made.

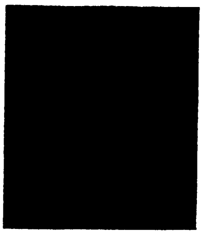
"Net" silk (silk threads reeled directly from the cocoon) comes to us in the form of what is known as "singles," a thread composed of just a few strands—say six. In the English "throwing mills" several of these singles are thrown together to make up a thread of the required thickness, with little twist if for weft, or, as it is termed, "tram," and much twist if for warp, or, as it is termed, "organzine" (see Fig. 25).

Waste silk is received in this country in three other forms, viz., wild cocoons, waste silk in the gum, and waste silk

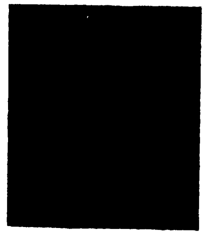
discharged. All these forms are, however, worked up on the same principle, which will be described later. It is reported that the tropical forests are full of a usable waste silk which may be gathered and placed on the market at 1*d*. per lb. If this be true, there are great possibilities before the waste silk industry.

The Cotton Industry.—The cotton industry seems to be of Asiatic origin, and appears to have appertained more particularly to the Mahometan religion, as we hear of Mahomet going about with the Koran in one hand, a sword in the other, and a cotton shirt upon his back. As already pointed out, flax, being a material more readily spun, would naturally claim first attention. It seems probable, however, that India was unsuitable for flax cultivation, while the cotton plant was evidently indigenous. Thus attempts would no doubt be made to utilize this very nice-looking fibre, and eventually cloths very suitable for the Indian climate would be produced. These fabrics being shipped to Europe no doubt ultimately, resulted in the cotton trade being established in various centres, but only on a very small scale. It was, as we have already seen, the mechanical era which gave life to the cotton trade and resulted in the development of the cotton-growing industry in the United States, the West Indies, Peru, the Sea Islands, Egypt, and later—under the auspices of the British Cotton Growing Association—in Africa. Our chief supplies of cotton still come from the United States. Egypt and the Sea Islands send us long-stapled cottons suitable for the Bradford trade, while Peru supplies us with a woolly cotton very suitable for blending with short wools for the Leeds and district trade.

In Fig. 3 the chief varieties of cotton are illustrated.

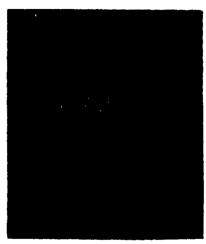


WEST AFRICAN. Gambia. from American seed.

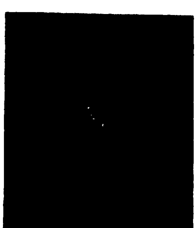


WEST AFRICAN. Lagos.

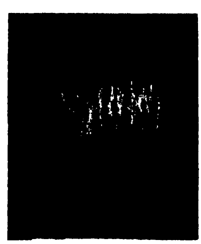
INDIAN. Oomrawattee.



INDIAN. Bengal.

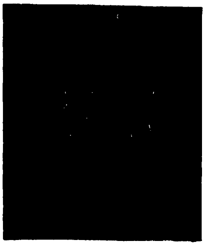


INDIAN. Broach.

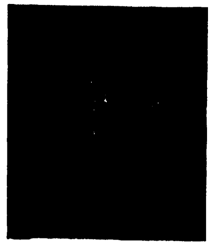


INDIAN. Tinnivelly.

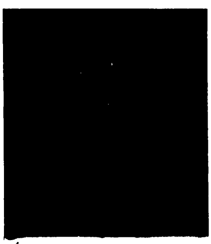
Fig. 3.—The Cotton Fibres of Commerce. Scale, ½ inch to 1 inch. Arranged and photographed by F. W. Barwick, Esq., of the Manchester Chamber of Commerce Testing House.



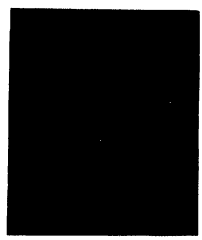
BRAZILIAN. Ceara.



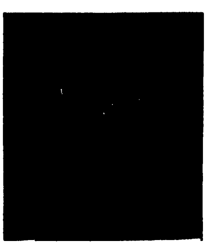
BRAZILIAN. Pernam.



BARBADOS. Sea Island.



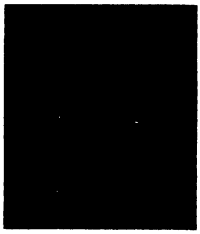
EGYPTIAN. Abassi.



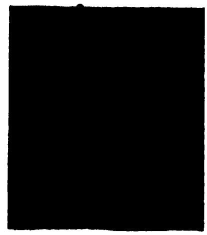
NYASSALAND. Egyptian.

EGYPTIAN. Mitafifi.

FIG. 3.—The Cotton Fibres of Commerce. Scale, ½ inch to 1 inch—*continued.*

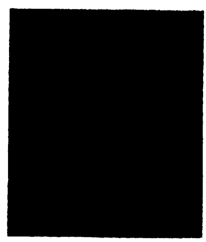


EGYPTIAN. Yannovitch.

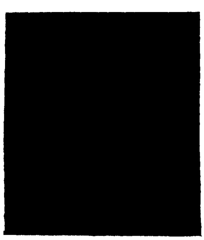


PERUVIAN. Smooth.

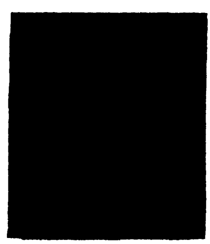
PERUVIAN. Rough.



PERUVIAN. Sea Island.

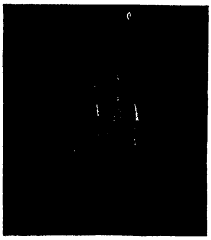


AMERICAN. Carolina Sea Island.

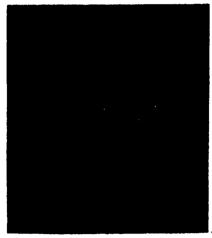


AMERICAN. Georgia Sea Island.

FIG. 3.—The Cotton Fibres of Commerce. Scale, ½ inch to 1 inch—*continued.*

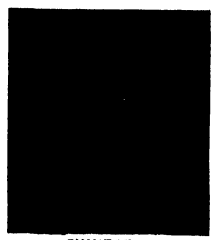


AMERICAN. Florida Sea Island.



AMERICAN. Texas.

AMERICAN. Upland.



CHINESE.

FIG. 3.—The Cotton Fibres of Commerce. Scale, ½ inch to 1 inch—*continued*.

The cotton-growing countries of the world are shown in Fig. 4, from which it will be noted that practically the torrid zone is the cotton zone. Of course soil and other conditions in part determine whether cotton can be grown, but it is evident that much heat is desirable and even necessary, and, as a consequence, that the best available labour is black labour. The United States has its "black belt," and in our attempts to grow cotton in our Colonies—and in the case of French Colonies also—it seems as though we must be largely dependent upon black labour.

The cotton fibre is produced on three varieties of plants,

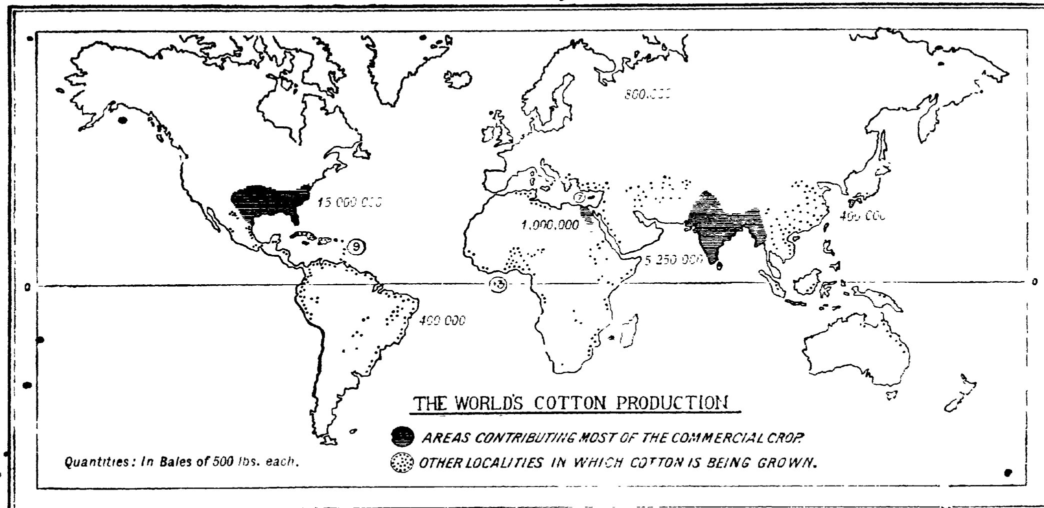


FIG. 4.

COTTON PRODUCTION OF THE WORLD.

	Bales[1]		Bales[1]
U.S.A.	15,000,000	Brazil	400,000
India	5,250,000	Other Countries	1,150,000
Egypt	1,000,000		
Russia	800,000	TOTAL	24,000,000
China	400,000		

[1] A Bale weighs about 500 lbs.

viz., Gossypium Barbadense, or the true Sea Island cotton plant, which, yielding the best type of cotton, is the original basis of much American, Egyptian, and Indian cottons; Arboreum or tree cotton, yielding a rougher cotton, coming to us from Brazil and Peru; and Herbaceum, or the variety of the ordinary cotton plant from which American cotton is largely produced.

The Flax Growing Industry.—The flax fibre is one of the oldest fibres of which we have any records. The Biblical references to flax (or linen) are numerous, and remnants of old linen fabrics are frequently coming to light in the exploration of the sites of the older civilizations. The writer has just been asked to analyse some linen fabrics dating back some 2,000 to 3,000 years. The following are the results:—

List VII.—Analysis of Mummy Cloths.

	To-day's Cloth Linen	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Weight per yard, 54 × 36	8 ozs.	$12\frac{1}{16}$ ozs.	$12\frac{7}{8}$ ozs.	10 [illegible] ozs.	$10\frac{3}{8}$ ozs.	$11\frac{5}{8}$ ozs.
Counts of warp	1/33·5 linen	1/20·7	1/10·3 linen	1/32·7	1/21·8 linen	1/29·1 linen
Counts of weft	1/31's linen	1/16's linen	1/10's linen	1/33·3 linen	1/18·4 linen	1/23·83 linen
Threads per inch	46	60	28	81	50	80
Picks per inch	13	21	18	37	25	27
Strength of warp (single thread)	30·72 ozs.		2·77 ozs.	-	1·31 ozs.	1·65 ozs.
Elasticity of warp (single thread)	·36″	—	·272″	-	·524″	·478″
Strength of weft (single thread)	31·66 ozs.	—	5·01 ozs.	—	6·23 ozs.	1·7 ozs.
Elasticity of weft (single thread)	·172″	—	·371″	—	·288″	3·34″

The flax fibre, coming as it does from the stem of the flax plant, naturally requires very different climatic conditions as compared with the cotton fibre. Although its cultivation is still very dispersed, the chief flaxes are Irish, Belgian, Dutch, German, and Russian. The stalks when judged to be ready are pulled up by the roots, either by hand or by one of the recently introduced pulling machines, placed in the dam to rot or " ret," as it is termed, dried and " scutched," this latter operation resulting in the cortical or non-fibrous matter being separated from the fibrous matter. Dew retting is practised on the Continent, and sometimes chemical retting also; but whichever system is adopted, the idea is simply to separate the fibres from the cortical and pith-like substance with which they are enveloped with as little damage to strength, length, and colour as possible. Many substitutes for flax have come forward from time to time, but none have stood the test, with the possible exception of cotton, which seems to have made considerable encroachments during the past few years. China grass or Ramie may in the future have some influence on the flax industry, but it has hardly yet been felt.

Other Vegetable Fibres.—It is useful to obtain a general idea of all the vegetable fibres, as one cannot foretell which type is likely to come more markedly into use, or what particular type of plant is likely to yield a fibre suitable for special and up-to-date requirements.[1] In List VIII. the origins of the various " vegetable hairs " are given. In List IX. the physical compositions of the vegetable fibres are given.

[1] The use of Sisal hemp in the place of horsehair by the Italians is a case in point.

List X. is a practically complete list of the vegetable hairs and fibres.

List VIII.—Vegetable Hairs.

Origin.	Natural Order	Typical Example
Entirely covering, or in part covering the seed	Malvaceæ	Cotton.
	Asclepiadaceæ	Madar Fibre of India
	Apocynaceæ	Periwinkle.
	Œnotheraceæ	Willow-Herb.
Contained in the flower.	Typhaceæ	Bullrush.
	Cyperaceæ	Cotton Grass.
Lining interior of fruit .	Bombaceæ	Horse-chestnut.
		Red Silk Cotton of India
Twigs and leaves . .	Filices	Ferns
	Muscineæ	Peat-moss Fibre

List IX.—Vegetable Fibres.

(*a*) Fibres formed of Single Cells:

Ramie—disintegrated.
China Grass—disintegrated.
Flax—disintegrated (*i.e.*, too far retted).

(*b*) Fibres associated in Bundles:

Jute—unbleached.
Flax.
Deccan Hemp.
Ramie—not disintegrated.
Hemp—well prepared.

(*c*) Fibres together with Medullary Ray Cells.

Sisal Hemp.

(*d*) Fibres together with Parenchyma Cells:

Sunn Hemp.
Mudar Fibre of India.

(*e*) Fibres and Vessels:

Phormium tenax or New Zealand Flax.
Musa or Manila Hemp.
Ananas or Pineapple and Banana Fibre.

List X.—Complete List of Vegetable Hairs and Fibres.

Technical Name.	Local or General Name and Location.	Scientific Name.
Cotton.	1. Tree Cotton	Gossypium arboreum.
	2. American, African, and Indian Cotton	,, Barbadense.
	2a. Sea Island Cotton.	,, maritimum, etc.
	2b. Peruvian or Brazil Cotton	,, acuminata.
	3. Asiatic Cotton	,, herbaceum.
Kapok	White Silk Cotton of East Indies	Eriodendron Anfractu.
Semal.	Red Silk Cotton of India	Bombax Malabaricum.
Silky Cotton	Down Tree of Armenia and Jamaica	Ochroma Lagopus.
,, ,,	White Silk Cotton Tree of India	Cochlospermum Gossypium.
Vegetable Silks	"Mudar" or "Yercum" of India	Calatropis gigantea. ,, procera.
,, ,,	Of Bengal	Beaumontea grandiflora.
,, ,,	"Yachan" of the Argentine	Chorisia insignis.
Flax.	Flax or "Lin"	Linum usitatissum.
Hemp.	Sunn Hemp	Crolalaria juncea.
,,	Sisal of India and Queensland	Sida rhombifolia.
,,	Manila Hemp	Musa textilis.
,,	Sisal Heneopien or Yucatan Hemp. (An aloe)	Agave rigida. Var. longifolia.
,,	Chinese Hemp	Abutilon, etc.
,,	Common Hemp	Cannabis sativa.
,,	Rajmahel Hemp of Northern India	Marsdenia tenacissima.
White Rope Fibre	Bombay or Manila Aloe of America and East India	Agave vivipara.
,, ,,	Istle of Mexico	,, heteracantha.
,, ,,	Maritius Hemp of South America	Fureroca gigantea.
Flax-like Fibres	Buaze Fibre of Guinea and Nileland, etc.	Securidnea longipedum culata.
,, ,,	Siberian Perennial Flax	Linum perenne.
Flax and Hemp Substitutes	Spanish Broom.	Spartum junceum.
	Kendu Fibre	Apocynum Venetum.
Jute	Jute of India and China	Corchorus capsularis.

LIST X.—COMPLETE LIST OF VEGETABLE HAIRS AND FIBRES—*continued.*

Technical Name.	Local or General Name and Location.	Scientific Name.
Jute . .	Jute of Calcutta . . .	Corchorus Olitorius.
,, . .	,, America . . .	Abutilon Avicennae.
,, . .	,, West Africa . .	Honckenya ficifolia.
Jute-like Fibres	Fibre from Lagos . .	Honckenya ficifolia.
China Grass	Tchon Ma (Temperate Zone)	Boehmeria nivea.
,, ,,	Ramie or Rhea (Torrid Zone)	Variatum tenacissima.
,, ,,	Canada Nettle Fibre . .	Laportea Canadensis.
Nettle Fibres	Tashiari (Himalayas) . .	Debregeasin Hypoleuca.
,, ,,	Nilgiri Nettle . . .	Girondina heterophylla.
,, ,,		Maontia purga.
,, ,,	Ban-Surat of India and Ceylon	Laportea crenulata.
,, ,,	Ban-Rhea of Assam . .	Villebrunea intergrifolia.
,, ,,	Urera Fibre of Natal . .	Urera tenax.
,, ,,	Mamaki of Pacific Islands .	Pipturus albidus.
,, ,,	Rere of Pacific Islands .	Cypholobus macrocephalus.
Palm Leaf Fibres	Oil Palm Fibre . . .	Eloesis Guineensis.
,, ,,	Gri-gri Fibre of West Indies	Astroca. .
,, ,,	Raffia of Madagascar and Africa	Raphia Ruffia.
,, ,,	Corogo Fibre of Cuba .	Acrocomia Lasiospatha.
Special Fibres	Plantain and Banana Fibre	Musa sapientium var. paradisiaca.
,, ,,	Pineapple Fibre of East India	Ananas sativa.
,, ,,	Caraguata of Paraguay .	Bromelia Argentina.
,, ,,	Pingum of Jamaica and America	,, ,,
,, ,,	Silk Grass of Jamaica and Tobago	Bromelias or Furcroea Cubensis
,, ,,	Madaguxar Piassava . .	Dicty osperwa Piassava.
Hibiscus or Mallows	Deccan Hemp. Also known as Kanaff and Ambari Hemp	Hibiscus Cannabinus.
,, ,,	Okro	,, esculentus.
,, ,,	Royelle or Red Sorelle .	,, Sabdariffa.
,, ,,	Maholtine (Africa and America)	Abutilon periplocifolium.

List X.—Complete List of Vegetable Hairs and Fibres—*continued.*

Technical Name.	Local or General Name and Location.	Scientific Name.
Hibiscus or Mallows	Ban-ochra of India, or "Toza" Fibre of West Africa	Urena lobata.
,, ,,	Indian Mallow Hemp . .	Abutilon Avicennæ.
Leguminous Order	Dhunchi Hemp of Assam .	Sesbania aculeata.
,, ,,	Ka Hemp of China and Japan	Pueraria Thunbergiana.
,, ,,	Maln Fibre of India and Ceylon	Banhima Vahlii.
Bowstring Hemps	Konje Hemp of Zambezi, etc.	Sansevieria Guinensis.
,, ,,	,, ,, ,,	,, longiflora.
,, ,,	Pangane Hemp of Pangane	,, Kukii.
,, ,,	Neyanda of Ceylon . .	,, Zeylanica.
,, ,,	Ife Hemp of South Africa .	,, cylindrica.
,, ,,	Moorva of India . . .	,, Roxburghiana.
,, ,,	Somali Land Fibre . .	,, Ehrenbergii.

The average lengths, practical and actual, and the average diameters of the principal vegetable fibres are given in List XI. In Fig. 5 the countries producing the more important vegetable fibres not specially dealt with here are indicated. The only fibres in these lists which call for special comment are hemp, jute, and the two forms of China grass.

Jute is the fibre from what is essentially a torrid zone plant and is largely used in the carpet industry for sackings, while hemp is not quite so much of a torrid zone plant and is more particularly used for ropes, especially for shipping, as it sinks in the water, while ropes of some other materials

do not sink so readily and are thus dangerous to small boats passing by.

LIST XI.—WORKING LENGTHS AND AVERAGE DIAMETERS THE PRINCIPLE VEGETABLE FIBRES (IN INCHES).

Name	Working Length.	Average Diameters.
	inches	inches
1. Agave Americana or Sisal Hemp. *Agave rigida var Sisalana* (True Sisal hemp)	36—60	$\frac{1}{250}$ – $\frac{1}{62}$ average $\frac{1}{130}$
2. Ananassa or Banana Fibre *Ananas Sativa* (Pineapple Fibre)	18—72	$\frac{1}{840}$ – $\frac{1}{240}$ „ $\frac{1}{410}$
3. Boehmeria Nivea or China Grass	up to 11	$\frac{1}{1750}$ – $\frac{1}{330}$ „ $\frac{1}{660}$
4. Boehmeria tenacissima or Ramie	ditto	ditto
5. (*a*) Common Hemp . .	18—84	
(*b*) Piedmontese or Giant Hemp	up to 144	$\frac{1}{1660}$ – $\frac{1}{500}$ „ $\frac{1}{1330}$
6. Corchorus olitorius or Jute.	60—120	$\frac{1}{1660}$ – $\frac{1}{500}$ „ $\frac{1}{1130}$
7. Crotalaria juncea or Sunn Hemp	72—144	$\frac{1}{2000}$ – $\frac{1}{830}$ „ $\frac{1}{1250}$
8. Linum usitatissimum or Flax	24—36	$\frac{1}{1150}$ – $\frac{1}{660}$ „ $\frac{1}{1000}$
9. Musa textilis or Manila Hemp	up to 60	$\frac{1}{500}$ – [illegible]
10. Phormium tenax or New Zealand Flax	36—132	$\frac{1}{312}$ – $\frac{1}{66}$ „ $\frac{1}{104}$

China grass (*Boehmeria nivea*) has so often been to the fore as a newly discovered fibre and so often proved a failure that one hesitates to speak of it. The Chinese, however, make such magnificent textures from this fibre that its prospects cannot be regarded as other than hopeful. Whether the Indian form of the fibre, ramie (*Boehmeria tenacissima*) as it is frequently called, will ever yield such a plastic wonderful yarn and fabric as the Chinese get from

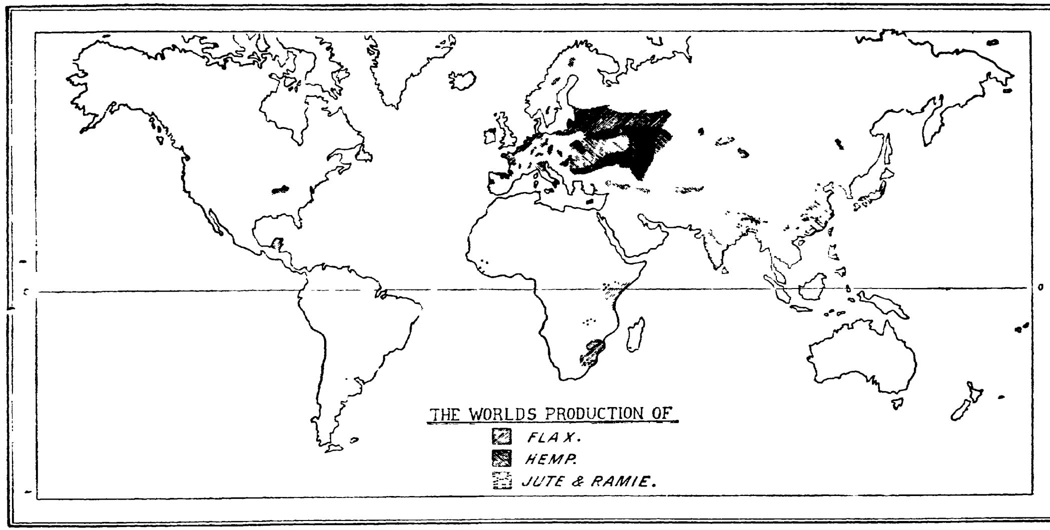


FIG. 5.

China grass (*Boehmeria nivea*) still remains to be seen. Certainly the possible need for indigo planters turning their attention to growths other than indigo should at least favour a really serious trial. The gums in China grass are the greatest difficulty, necessitating its being prepared in a way entirely different from linen: when it is satisfactorily prepared it is so silky that waste silk machinery is the most suitable for dealing with it. The Heilmann wool comb has also been found to be very suitable for combing the slippery fibre.

At the present moment a great revival in the New Zealand flax (*Phormium tenax*) industry is taking place. Whether success will attend the endeavours being made remains to be seen, but of this we may be certain, that there are still many fibres only partially exploited, and many which have not even been touched, which in the future are undoubtedly destined to play a useful part.

Notes on the Chemical and Physical Structures of the Fibres.—The textile fibres of commerce naturally group themselves into six well-defined groups, viz., the animal fibres, the vegetable fibres, the animal-vegetable or insect fibres, the mineral fibres, the remanufactured fibres, and the artificial fibres.

Of the first class the normal wool fibre may be taken as representative. It is composed of carbon, oxygen, nitrogen, hydrogen, and sulphur,[1] and when burnt emits a disagreeable odour largely due to the liberation of ammonia, which serves to distinguish it from cotton and most other fibres. It does not burn with a flash, as does cotton, but rather shrivels away, leaving a bead of burnt matter. Wool has marked powers of causing dissociation of certain metallic salts, this forming the basis of the mordanting of

[1] In what manner these elements are combined chemists are still uncertain.

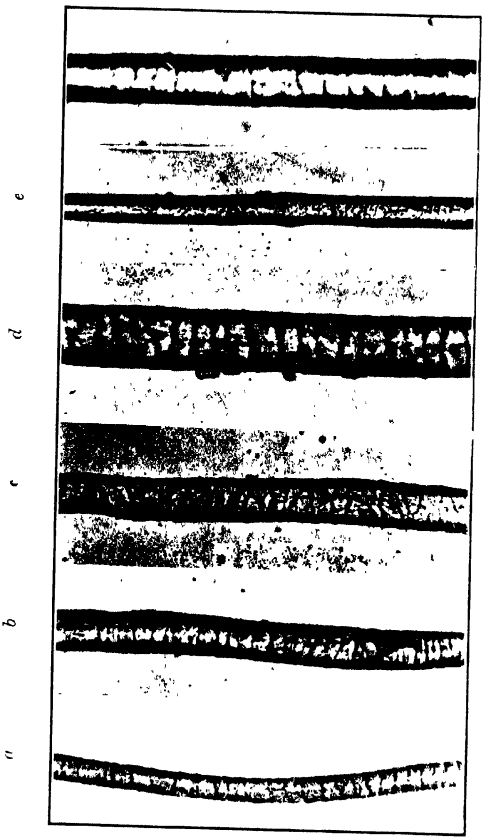


FIG. 6.—Micrographs of Wool Fibres: (a) Merino (Australian), (b) Southdown (English), (c) Cross-bred (New Zealand), (d) Lincoln (English), (e) Alpaca (South American), (f) Mohair (Turkish).

wools prior to dyeing. It is open to doubt as to whether the action of dyeing is entirely a chemical or partly a physical action. In the case of indigo dyeing, for example, there seem marked indications that the action is purely physical.

On the other hand, this cannot be said with the same certainty of most other dyes. Physically, the most remarkable thing about wool is its exterior scale structure (clearly shown in Fig. 6). Various qualities of wools have this exterior scale structure developed in different degrees. Wools seem to shrink chiefly because the fibres of which yarns and fabrics are composed tend to revert to their original curled condition as grown on the sheep's back, when treated with warm water. Wools felt chiefly by crimping up, either on yarn kinks or nodes or on the curvature introduced into the threads and picks by the weave. Thus the wool fibre seems in itself to be much more stable than has been heretofore supposed, and milling is chiefly attributable to, as it were, the accordion pleating of the yarn and, more particularly, of the fabric. Hairs only show more or less faint indications of the scale structure, and consequently do not felt so readily. Upon the other hand, they are usually more lustrous, their uncorrugated and unbroken surface reflecting the light intact. In fineness wool fibres vary from $\frac{1}{500}$ to $\frac{1}{3000}$ of an inch in diameter, but there is no well-defined relationship between fineness and length, although the Bradford quality numbers, such as 30's, 40's, 50's, 60's, 70's, etc., no doubt suppose some general coincidence between length and fineness of fibre. In List XII. the corresponding Bradford and American qualities are given. A year's growth in length may equal anything from 1 or 2 inches to 12 or 16 inches, a fair average being 7 to 8 inches. Wool, however, if left unclipped, will grow sometimes to 40 inches in length, and fleeces are on record weighing 57 lbs. The length of the wool fibre, as will be demonstrated later, largely determines the method of preparing and spinning it into yarn.

Of the second class, cotton is the most representative of

List XII.—Comparative Wool Qualities.

English.	U.S.A Domestic.	U.S.A. Territory.	Canadian.
66's–74's	Full blood.	Fine.	
60's–66's	Three-quarter blood.	Fine medium.	
54's–60's	One-half blood.	Medium.	Fine.
48's–54's	Three-eighths blood.	Three-eighths blood.	Fine medium.
44's–48's	One-quarter blood.	One-quarter blood.	Medium.
40's–44's	Low one-quarter blood.	Low one-quarter blood.	Low medium
36's–40's	Common.	Common.	Coarse.
32's–36's	Braid.	Braid.	Luster.

the "seed-hairs." It is nearly pure cellulose, the formula for which is given by A. G. Green as

$$\begin{array}{l} HC(OH)\text{—}CH\text{—}CH\text{—}OH \\ \qquad\qquad\quad >O \quad >O \\ HC(OH)\text{—}CH\text{—}CH_2. \end{array}$$

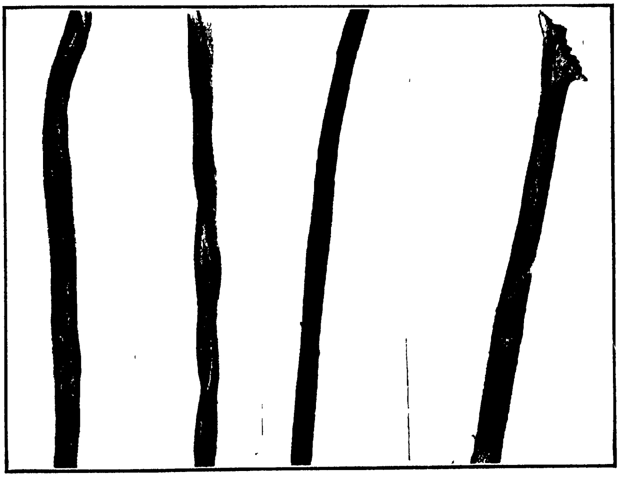
Flax and the other "stem-fibres," while largely composed of cellulose, are much less pure in composition, and in many cases by their very impurities may be distinguished from one another (see List IX.).

Physically, cotton appears to take the form of a flattened, collapsed, twisted tube; in fact its form is best suggested by a thin indiarubber tube out of which the air has been drawn. If unripe, the characteristic feature of twist is absent, and the cotton neither dyes well nor does it spin to advantage. In length the cotton fibre varies from $\frac{7}{8}$ of an inch to $1\frac{3}{4}$ inches and in diameter averages about $\frac{1}{1344}$ of an inch. Fig. 7 illustrates some interesting features respecting the structure of the cotton fibre.

The chief characteristic of flax as viewed under the microscope is the appearance of nodes, these, no doubt, being limitations of growths. Flax may readily be recognized by the property it possesses of developing curious cross striations

when treated with nitric acid and then sulphuric acid and iodine. Most of the vegetable fibres may be recognized by some special chemical reaction. Thus jute, for example, may be distinguished from flax, etc., by the action of an acidulated

a *b* *c* *d*



FIGS. 7 and 8.—Micrographs of Cotton Fibres: (*a*) unripe fibre, (*b*) ripe fibre, (*c*) mercerized fibre. Micrograph of Silk Fibre: (*d*) illustrates the twofold character of the silk fibre and the splitting and expansion of the fibrils which occur in some Tussah Silks.

alcoholic solution of phloroglucine, flax being unchanged, while jute is stained an intense red.

Of the third class silk is the representative fibre. In most of its chemical reactions silk is akin to wool, but there are differences which enable the dyer to cross-dye silk and wool

goods—*i.e.*, to dye the silk one colour and the wool another colour, although there are obvious limitations in this respect. The silk fibre consists of two distinct parts, a central portion and a coating of substances readily removable by hot water, termed the "silk gum." The central portion of "fibroin" has approximately the composition : $C_{15}\ H_{23}\ N_5\ O_6$. The silk gum, which often forms as much as 20 to 30 per cent. of the natural silk fibre, is usually boiled off, and only too often weighting added, which has a deleterious action on the wearing qualities of the silk. Why silk should so readily weight-up does not entirely admit of a satisfactory explanation. It is, of course, a most expensive fibre, and as weighting agents cost 1*s.* per lb. and as silk sells at 12*s.*, weighting naturally pays well. Physically, silk may be defined as a long fibre (cocoons contain from 400 to 1,500 yards) of a twofold character, this being due to the silk fluid issuing from a gland on each side of the silkworm, the ducts from these uniting in the head of the worm. Under the microscope the fibre appears more as a glassy rod of fairly round form (Fig. 8), but from time to time the twofold character is perceptible in following along the fibre. In fineness it is from $\frac{1}{500}$ to $\frac{1}{1600}$ of an inch, the finer being the cultivated silks and the coarser the wild silks. A peculiar feature of the wild tussah silks is that upon the fibre being cut it breaks up into a number of fibrils, forming a bush-like end. This makes the fibre specially suitable for the production of plushes.

The mineral fibres are principally glass, tinsel, and asbestos. As they are of very limited application, their chemical composition and physical qualities need not be fully discussed here. Glass naturally partakes of the qualities of ordinary glass, but is much more flexible than would be naturally

supposed. Tinsel is made from copper, aluminium, and other metals drawn out, and partakes naturally of the qualities of the metals from which it is made. Asbestos possesses characteristics which cannot be well defined on paper. As woven into cloth it is irregular, lumpy, soft, and plastic. It is naturally mostly employed next to heated surfaces, for firemen's jackets, etc.

The remanufactured fibres can only claim distinctive treatment from the physical point of view. They mostly consist of animal fibres which have been broken up in length and the scale structure of which has been partially damaged. The important quality of elasticity has also been seriously interfered with.

The artificial fibres are of such importance that it has been deemed advisable to devote a special chapter to them.

Notes on the Effects of Chemical Re-agents on the Textile Fibres.—The effects of even simple re-agents are so marked and so diverse that it is very necessary to have an accurate and extensive knowledge of such under all the varying conditions obtaining in practice. For instance, boiling water will disintegrate and weaken wool while it strengthens cotton. Again, sulphuric acid and caustic soda have very different actions on the cotton and wool fibres. Sulphuric acid with heat may be employed to disintegrate the cotton out of a cotton and wool fabric, while caustic soda may equally well be employed to dissolve the wool from the cotton. Cold strong caustic soda, however, may be employed to mercerize the cotton in wool and cotton goods without detriment to the wool. It is thus evident that absolute knowledge based upon incontrovertible experience is necessary if mistakes are to be avoided and the best results obtained.

CHAPTER III

THE MERCERIZED AND ARTIFICIAL FIBRES EMPLOYED IN THE TEXTILE INDUSTRIES

MERCERIZED COTTON.

THE term mercerization is now applied to a process by means of which cotton yarn or cloth is rendered lustrous and silky in appearance, and the importance of the process has made enormously rapid development since its introduction in 1895. The production of lustre is accompanied by considerable modifications in the structural appearance, chemical character, and dyeing properties of the fibre, and these latter effects of mercerization were first noticed and investigated by John Mercer in 1844.

Mercerization without lustre is carried out by steeping the dry cotton in a cold concentrated solution of caustic soda ($NaOH$, 50° Tw.) for a few moments, and then well washing to remove the alkali. This changes the microscopic appearance of the individual cotton fibres from that of flattened spiral tubes with thin walls and a relatively large central cavity to that of more or less cylindrical non-spiral tubes with thicker walls. The effect in mass of this modification of the fibre is that the threads contract in length, become somewhat thicker, and much stronger; the dyeing properties being also considerably modified. Chemically the process results in the formation of a definite chemical compound of

cellulose and caustic soda $(C_6H_{10}O_5 \cdot NaOH)x$ in a state of hydration. On washing, this is decomposed, the alkali being removed and the cellulose regenerated as a hydrate $(C_6H_{10}O_5 \cdot H_2O)x$ which permanently retains the altered appearance and properties above noted.

The natural shrinkage thus brought about is made use of in the production of *crepon* effects on mixed cotton and wool fabrics.

Lustreing by mercerization is obtained by a very slight modification of Mercer's original process; the shrinkage of the yarn or cloth which would naturally take place being prevented by mechanical means.

"Mercerization" may also be brought about by the use of substances other than caustic soda, *e.g.*, sulphuric, nitric, or phosphoric acid or zinc chloride; the use of these being mentioned in Mercer's original patent. Sodium sulphide has also been proposed, but none of these bodies are of any practical importance in this connection.

The Process.—The essentials of the process are very simple, but for economical and efficient working the following points require attention:—(1) The caustic soda solution should be used at a strength of about 55° Tw. and as cold as is possible without artificial cooling; (2) the material must be thoroughly and uniformly impregnated; (3) the material must be kept in a state of uniform tension until the water has decomposed the alkali cellulose; (4) as much of the caustic soda as possible must be recovered; (5) the cotton must be of long staple and the threads must not be too tightly twisted.

Many different mercerizing machines have been introduced, and their relative success depends upon the degree

to which they satisfy conditions Nos. 2, 3, and 4 specified above, and are economical as regards output and labour required. The soda recovery apparatus is another important feature of a modern mercerizing plant. In this the wash waters are evaporated to mercerizing strength, and the recovered soda is treated with lime to recausticize the portion which has been converted into carbonate during the various operations.

Bleaching and Mercerizing.—If cotton is bleached after mercerization the process of bleaching does not destroy the lustre of the mercerized fibre; but this sequence of operations offers no advantage, and the maximum lustre is always obtained when the material is subjected to as little treatment as possible after mercerization. Treatment with bleaching powder after mercerizing is also liable to rot the fibre by oxidation.

The Dyeing of Mercerized Cotton.—It has already been mentioned that mercerized cotton has a much greater affinity for many mordants and dyes than has the untreated fibre. The effect is greatest in the case of cotton mercerized without tension, and diminishes somewhat as the tension is increased, being least marked in fully lustred cotton. The difference in the chemical properties of mercerized and unmercerized cotton is the main cause of their different behaviour in dyeing, but structural or physical change has also a considerable effect.

Irregular mercerization is a frequent cause of irregular dyeing, and special precautions must be taken when the cotton is subsequently to be dyed in pale shades. Some further information regarding the dyeing properties of mercerized cotton will be found in the next chapter, p. 87.

Crimp effects on Cotton are obtained by mercerizing cotton cloth in stripes or other patterns by a printing process, the natural shrinkage of the mercerized portion producing the crimp. If printed and mercerized under tension, lustre patterns may be obtained on cotton cloth.

Crepon effects on Union Cloth.—Wool fibre is practically unaffected by caustic soda of mercerizing strength, and if suitably woven with cotton and the fabric mercerized, the shrinkage of the cotton throws up the wool into loops or knots. Silk-cotton unions may be similarly treated, but require great care in manipulation. To ensure that the wool or silk is not injured it is usual to artificially cool the caustic solution before and during use.

The Schreiner Finish.—This process of increasing the lustre of cotton is so closely connected with mercerizing lustre from the practical standpoint that mention should be made of it here. It consists in subjecting cotton cloth to the action of an engraved steel roller under great pressure. The engraving consists of very fine serrations, numbering 400 to 700 per inch, and these produce optically reflecting surfaces upon the threads which very greatly enhance the lustre of the material. Cotton lustred by mercerization and subsequently treated with the Schreiner calender rivals silk in appearance.

The Production of Mercerized Cotton is one of the most important recent developments in the textile trade, having practically enriched it with a new fibre almost as lustrous as silk, and much less costly. One of the main defects of mercerized cotton is that its lack of elasticity renders fabrics made from it very liable to crease.

Test for Mercerized Cotton.—A solution of iodine in

saturated potassium iodide solution colours both ordinary and mercerized cotton a deep brown. On washing with water, the colour of mercerized cotton changes to a blue black, which fades very slowly on long washing, whereas ordinary cotton rapidly becomes white on washing.

Artificial Silk.

The silk fibre, consisting of the solidified fluid of the silk glands of the worm, is devoid of cellular structure. Wool and cotton, on the other hand, are highly organized fibres from the structural standpoint, being composed of a vast number of individual cells built up in a definite and orderly manner. It is thus impossible to conceive of the mechanical production of a fibre resembling wool or cotton in character; but in its broadest outline the problem of the production of a fibre similar to silk is not a difficult one.

The problem involves two main features—first, the production of a viscous liquid analogous to that naturally existing in the silkworm glands, and, secondly, the mechanical conversion of this into fine fibres.

The second part of the problem offers no insuperable difficulties; in fact artificial silk fibres are now produced which are much finer than those of natural silk (Thiele silk).

The composition of the viscous liquid may be chemically similar to natural silk or may be of an entirely different character. The first artificial filament which resembled silk in appearance was spun glass, from which fabrics of brilliant lustre and considerable softness may be produced. These are, however, of little value, since the fabric rapidly disintegrates on account of the brittle nature of the fibre

Vanduara Silk' is obtained by using gelatine as a basis, the threads, after spinning, being treated with formaldehyde to render them insoluble in water. It is a beautifully lustrous fibre, and fairly strong and elastic in the dry condition, but if wetted it becomes extremely tender. It is now little, if at all, used.

Gelatine may also be rendered insoluble by the combined action of chromic acid and light, and this has formed the basis of an artificial silk process; but no practical success has been achieved on these lines.

Cellulose Silk.—All the commercially produced artificial silks are obtained by using some form of cellulose as a basis, and in this connection may be mentioned the names of *De Chardonnet*, *Pauly*, *Lehner*, *Vivier*, *Thiele*, *Cross*, *Bevan*, *Stearn* and *Bronnert* silks. These are known under such names as "*Collodion silks*," "*Glanzstoff*," "*Lustro-cellulose*," and Courtaulds' or "*Viscose silk*."

Cellulose, the chemical basis of cotton linen, wood, and the structural portion of vegetable growth generally, is chemically a very inert substance, and only a few ways of dissolving it are known.

(1) When converted into nitro-cellulose by treatment with nitric acid, cellulose becomes soluble in alcohol-ether. The various "collodion" silks are thus produced.

(2) Cellulose is soluble in a concentrated solution of zinc chloride, or

(3) In an ammoniacal solution of hydrated oxide of copper.

(4) If cotton is mercerized with caustic soda and treated with carbon disulphide while still saturated with the alkali, it forms a new chemical compound (cellulose thiocarbonate) which is soluble in water; the solution being known as "viscose."

(5) Acetates of cellulose may be produced which are soluble in various solvents.

Each of these five methods of dissolving cellulose forms the basis of a commercial process of manufacturing artificial silk.

(1) *Collodion Silk.*—This was the original artificial silk, and was first patented by de Chardonnet in 1886, after surmounting many difficulties, due chiefly to the inflammability and lack of strength of the fibre. The chief names connected with this product are those of De Chardonnet, Lehner, and Vivier.

(2) *Bronnert Silk* is made from a zinc chloride solution of cellulose, but this process has not made such rapid development as

(3) The *Cuprammonium process*, which yields the *Pauly*, *Linkmayer*, and *Thiele* silks, which latter is, as regards appearance and handle, almost indistinguishable from natural silk.

(4) The *Viscose Silk* of Cross, Bevan and Stearn is now of chief importance. Its production has been mainly developed by Messrs. Courtaulds', who manufacture it on a very large scale. The total world's production of artificial silk is now well over 10,000 tons per annum, of which probably 85 per cent. is Viscose silk.

(5) *Acetate Silk* has recently (1920) been placed on the market by the British Cellulose Co., Ltd.

Properties of Artificial Silk.—The characteristic properties of natural silk which render it so much esteemed as a textile material are its beautiful lustre, softness, elasticity, strength, and covering power, and the ease with which it can be dyed, With regard to lustre the artificial silks exceed the natural fibre, some having almost an undesirable metallic lustre. In softness and general handle certain varieties of artificial silk are somewhat deficient, but this defect has been overcome by

building up the thread from a large number of fine filaments, so that a thread of 40 denier may contain 40 to 80 of such filaments. Such artificial silks are equal to natural silk in softness and covering power. All artificial silks need special care in winding and in the loom.

In *elasticity and strength* artificial silks are somewhat deficient even when dry, and when wetted the defect is greatly accentuated. This renders careful treatment in dyeing very necessary.

Dyeing Properties. The various artificial silks differ considerably in dyeing properties. Collodion silks dye for the most part similarly to natural silk, while Pauly, Linkmayer, and Thiele silks and Viscose silk behave much more like cotton (see Chapter IV.).

Fabrics entirely composed of artificial silk have only recently been successfully produced, but it has for some time been largely used as weft yarn, and still more largely in the production of plushes and trimmings.

CHAPTER IV

THE DYEING OF TEXTILE MATERIALS

DYEING processes vary in character according to the textile material operated upon and the nature and properties of the colour desired. Thus, *e.g.*, the production of scarlet shades on wool and on cotton requires entirely different processes, and the method used in producing a blue on wool with indigo is quite distinct in character from that required for dyeing logwood black.

Many (but by no means all) of the processes used in cotton dyeing are carried out without heat. Silk is usually dyed in lukewarm baths, while wool dyeing processes are usually conducted in boiling baths. Silk is almost invariably dyed in the hank or warp; cotton usually in the form of hank, cop (or bobbins), warp, or cloth; while wool is dyed at all stages of manufacture, viz., as loose wool, sliver, hank, warp (occasionally), and in piece.

The various dyeing materials are applied to the fibre in aqueous solution, from which they are withdrawn either partially or completely by simple absorption or by some chemical action of the fibre. So-called "dry dyeing" is a special process used by garment dyers in which benzine or other similar organic solvent is employed instead of water. The object of the process is to avoid the removal of the stiffening materials present in the fabrics.

The number of distinct dyes now on the market is very large (upwards of 1,000), and with a few notable exceptions they are all chemically derived from coal tar products. Of the natural dyes still commercially used, indigo and logwood are much the most important; but a few others, such as cochineal, fustic, and orchil, find a more limited application.

In addition to the dyestuff itself, various chemical bodies are required in dyeing operations, some being essential constituents of the ultimate dyed colour (mordants), and others merely aiding the solution or fixation of the dye (assistants). In this short summary of dyeing operations no exhaustive treatment either of dyestuffs, mordants, or assistants is possible; but many examples of each will be incidentally mentioned.

Mordants. This term is applied to substances which serve a double purpose, viz., they unite both with the fibre and with the colouring matter, and thus fix the latter on the fibre, and at the same time the new chemical compound formed by mordant and dyestuff has frequently an entirely different colour to that of the dyestuff itself, being in fact the real dye. The mordant is usually applied in a separate process before dyeing; but with an increasing number of dyes the mordanting comes last, and in some cases the mordant and dye are used together. The chemical nature of the mordant must depend upon that of the dyestuff. In wool dyeing certain metallic salts are largely used (bichromate of potash, alum, sulphates of copper and iron), whereas in cotton dyeing tannin matters are largely used as mordants for the basic dyes. In dyeing silk, dyestuffs which do not require mordants are chiefly employed.

Assistants.—A large variety of acids, alkalis, and salts

are used for various purposes in dyeing. The acids chiefly employed are sulphuric (vitriol), acetic, and formic, all of which are used with acid dyes. Carbonate of soda (soda ash), caustic soda, and ammonia are the chief alkalis used, whilst sodium chloride (common salt), sodium sulphate (Glauber's salt), and many other salts are employed in various cases as additions to the dye-bath. The *rôle* of assistants is very varied and cannot be shortly summarized.

Dyestuffs.—In view of the enormous number of dyestuffs it is impossible to deal with them without adopting some method of classification. Various methods of classification may be adopted, but that based on method of application is the most convenient for the present purpose, and this distinguishes the following groups:—(1) *Mordant dyes*; (2) *Acid-mordant dyes*; (3) *Acid dyes*; (4) *Direct dyes*; (5) *Basic dyes*; (6) *Dyes applied by special processes*.

(1) *Mordant dyes.*—Many dyes of this group are "fast dyes," and are extremely resistant to the action of the light and to such processes as washing and milling (fulling). They must be used in conjunction with some metallic mordant, such as bichromate of potash or alum, and can be applied to all fibres, though they are chiefly used in wool dyeing.

Example.—Boil the wool for one to two hours in a solution of 3 per cent. bichromate of potash (calculated on the weight of the wool); wash and boil in a separate bath with the dyestuff.

Dyes of this group are not, as a rule, capable of producing brilliant colours, being chiefly used for blacks, navies, browns, olives, etc. The group includes the alizarin, anthracene, chrome and diamond dyes, logwood, madder, and many

others. Cochineal also belongs to this group; in conjunction with tin mordant it produces a brilliant scarlet colour.

(2) *Acid-mordant dyes.* — These dyestuffs have very similar properties to the last group, but are applicable only to wool. They are of increasing importance and include the acid-alizarin and acid-anthracene dyes, the cloth reds, etc. They are applied in an acid bath and subsequently treated with a metallic mordant.

(3) *Acid dyes* are largely used both in wool and silk dyeing, but are not applicable to cotton. They are not used in conjunction with mordants, but are dyed direct with the addition of 2 to 4 per cent. (sulphuric or formic) acid to the dye-bath. They vary considerably in regard to fastness to light, some being very fast and others comparatively fugitive; but as a class they are not so fast as groups (1) and (2). They are also more readily affected by washing and milling (fulling).

This group is a very numerous one and comprises a complete range of shades from the brightest primary colours to black.

(4) *The Direct dyes.*—Members of this group have the special property of dyeing cotton without the aid of any mordant. Many of them are also used on wool, on which fibre they produce shades which are fast to milling. They are also used on silk. The method of application to any fibre is very simple, the only addition required being salt or Glauber's salt, with or without a little soda ash. By certain methods of after-treatment ("saddening" and "developing") some of these dyes are rendered much faster than when dyed in the direct manner. Practically the same complete range of shades is obtainable with the direct dyes as with the acid colours.

(5) *The Basic Colours.*—This group is numerically smaller, and in range of colour less extensive, than the groups of mordant, acid, or direct dyes. It includes, however, the most brilliant dyes known, rhodamine pink, auramine yellow, malachite green, methylene blue, magenta, and methyl violet being well-known examples. The basic dyes (with few exceptions) are not used on wool, since they are apt to rub (smear). On silk they are dyed direct, with the addition of a little soap, but cotton requires to be previously mordanted with tannic acid or some form of tannin matter. The most serious defect of this group of dyes, as a class, is that they are fugitive to light.

(6) *Dyes applied by special processes.*—**Indigo.**—This is the most important of all dyestuffs, still retaining its pre-eminence in spite of the large number of competitors and substitutes which have been introduced. It is used very largely both on wool and on cotton materials, but less commonly on silk. Being quite insoluble in water, a special method of application is necessary, and this is the same in principle whether used for wool or cotton. The process is based upon the fact that when indigo is acted upon by what are chemically known as reducing agents, the blue insoluble substance is converted into a colourless body which is soluble in alkalis. The necessary ingredients in an indigo vat are thus the indigo, some alkali (lime or soda), and some reducing agent; and the various kinds of vats in use differ chiefly in the nature of the latter. In the "woad vat," which is largely used in the dyeing of wool materials, the reduction is due to a specific bacterium which is introduced by the woad; certain other substances, such as bran, madder, molasses, etc., being also necessary to supply

foodstuff for the bacteria. This vat is used warm, and when once "set" may remain in use for several months, being systematically replenished with indigo, etc. The "hydrosulphite vat" contains indigo, lime (or soda), and hydrosulphite of soda, and may be used warm (for wool) or cold (for cotton). The "copperas vat" is made up with indigo, lime, and copperas (ferrous sulphate) and is used for cotton.

The process of dyeing in the indigo vat consists in saturating the material with the vat liquor and, after squeezing out the excess, exposing the material to the air, when the colourless reduced indigo becomes rapidly re-oxidized on the fibre into the original blue indigo.

Synthetic or "artificial" indigo, being chemically identical with natural indigo, is applied in the same manner. There are now several distinct but closely associated synthetical dyestuffs in addition to the true "artificial indigo." They are all dyed in similar manner, but yield a variety of blue, purple, red and brown shades.

In dyeing dark indigo blues on wool materials it is usual to "bottom" the wool with some other (cheaper) colouring matter before dyeing in the vat. Frequently also the indigo is "filled up" or "topped" after vatting, either with the same object or in order to impart a "bloom" to the colour. Heavy shades of pure vat blue are rarely met with.

Well-dyed indigo vat blue produces extremely fast shades on wool. It retains its fine bloom and brilliancy almost indefinitely, and washing does not affect it in the least. It also withstands sea air, but of course, if "bottomed" or "topped," the associated dyestuffs may be affected. The

one defect of vat blue is that the colour "rubs off." This cannot be entirely prevented, but the more skilfully the dyeing process is carried out the less noticeable is the defect. Indigo blue is less fast to light on cotton than on wool.

The Vat dyes.—This term is applied to an important group of modern dyes which, like indigo, are applied in the reduced condition by the vat method. There are two sub-groups, the "indigoid" and the "anthracene" vat dyes, the former being chemically closely related to indigo and the latter to the alizarin dyes. Although some of them may be applied to wool, they are of the most value as cotton dyes, as by their use it is possible to produce a wide range of practically "fadeless" colours.

The Sulphide dyes are of great importance for the production of "fast colours" on cotton. The group includes many blacks, blues, dark greens, browns, and yellows, but at present a good red of this series has not been put on the market. They are most conveniently dyed on warps, but are also used on pieces and hanks. The general method of application is to dissolve the dyes (which are insoluble in water) in a solution of sodium sulphide, some sodium carbonate and Glauber's salt being also frequently used in the dye-bath. The baths are used warm and dyeing must take place below the surface of the liquor.

A very serious defect of the sulphide dyes is that cotton dyed with them is liable to become tender (rotten) on storing. This is due to the slow development of sulphuric acid by oxidation of the sulphur associated with the dyestuff. The defect is most liable to occur in stoved union goods. The tendering may be prevented by any treatment

which leaves the goods in a permanently alkaline condition.

The sulphide dyes are fast to "cross-dyeing" and to alkalies and milling.

Aniline black is another dye which requires a special method of application, being of such an insoluble and chemically resistant nature that the only practicable method of using it is to actually produce it on the fibre by suitable chemical reactions. It is the most brilliant, dense, and permanent black which can be produced on cotton, and is dyed, chiefly on cotton yarn and pieces, in large amount. It is little used on wool or silk. Aniline black is obtained by the oxidation of aniline, a basic substance ($C_6H_5 \cdot NH_2$) produced from the coal tar hydrocarbon benzene (C_6H_6). A bath is prepared containing aniline oil, hydrochloric (or other) acid, and some suitable oxidizing agent. The cotton is saturated with this liquor and then "aged" (hung in a warm, moist atmosphere) or otherwise subjected to oxidizing conditions.

As in the case of indigo, aniline black is apt to "rub off" if badly dyed. Another defect which can be avoided by skilful dyeing (but only in this manner) is tendering of the fibre. This may be due either to undue acidity of the bath or to oxidation of the fibre.

Aniline black is a very "fast" colour. It withstands "cross-dyeing" perfectly and is also fast to light, washing, milling, etc. If dyed in a special manner it is unaffected by the very severe processes involved in cotton bleaching ("bleaching black"). It is most readily attacked by reducing agents, such as sulphurous acid, which turn it green, and long exposure to the atmosphere of a room where gas is burnt may thus cause "greening."

The Ingrain dyes.—The term "ingrain" as applied to dyes is a very old one. It is now used to designate a certain series of cotton dyes—chiefly reds—which are produced on the fibre.

Para (or paranitraniline) red is produced on yarn, warps or pieces, by first impregnating the cotton with a colourless solution of β naphthol, drying and "developing" by passing through a solution of paranitraniline treated with nitrous acid. The red is produced instantaneously. It is a very brilliant and fairly fast colour and is largely used as a substitute for Turkey red.

Primuline red is a somewhat similar dye, but is produced in the reverse way. The cotton in this case is dyed with primuline (a direct yellow dye), then treated with nitrous acid, and the yellow colour "developed" into a red by treatment with β naphthol.

There are also black, blue, purple, brown, and yellow dyes belonging to this series, but they are not much used.

Turkey red has somewhat of the same pre-eminence as a red on cotton that indigo vat blue has on wool. Its production is a special branch of dyeing, carried on in special works in a few districts (Manchester and Glasgow). It really belongs to the class of mordant dyes, but is produced in such a special manner that it may more fittingly be mentioned in the section of "special dyes." The cotton, in yarn or piece goods form, is first treated with olive or castor oil, then mordanted with alumina, and finally dyed with alizarin. Many subsidiary processes are necessary in order to thoroughly fix the colour and develop its full brilliancy. Well dyed Turkey red is a bright scarlet colour and is very fast to all influences.

Water used in Dyeing.

In no industry is a plentiful supply of pure soft water of more importance than in dyeing, the use of unsuitable water resulting not only in considerable waste of material, but also in bad work. Perfectly pure water is, however, never available in sufficient quantity, since it is not found in natural sources, and thus the difference in the quality of various water supplies is largely one of degree. The chief impurities naturally present in water are the carbonates, sulphates, and chlorides of lime and magnesium, which impart to the water the property of forming a curdy scum with soap, usually termed "hardness." A "soft" water is most suitable for dyeing, but "permanent hardness," which is due to sulphates and chlorides, is much less harmful in dyeing than the "temporary hardness" caused by carbonates. In wool scouring or any other process in which soap is used, both kinds of hardness are equally injurious, and the lime-soap curd which is produced adheres to the fibre and causes much subsequent trouble and damage in dyeing and finishing operations. The wastefulness of hard water is well illustrated by the fact that 1,000 gallons of water of only 10° hardness will destroy and render not only useless, but dangerous, 15 to 20 lbs. of ordinary soap.

Iron is a not infrequent impurity in water supplies, particularly such as are obtained from coal measures, and water containing iron is totally unfit for use in a dye-house, since iron has a dulling and darkening effect on many dyes.

Water of less than 5° of hardness may be considered as of good quality for dyeing, particularly if the hardness

is mainly "permanent." If the only available supply exceeds 8° or 10° in hardness it should be "softened" by chemical treatment before use. This can usually be done at a cost not exceeding 1*d.* to 6*d.* per 1,000 gallons.

The organic impurities in water have usually little effect on dyeing processes, unless the water is contaminated with the refuse from other works.

Reference may also be made to the desirability of using soft water for steam-raising in order to prevent the production of "boiler scale."

Interdependence of Processes.

In order to produce the best possible result it is not only necessary that the raw material of which a textile fabric is composed should be of good quality, but that all the various operations involved in its manufacture should be carried out with proper skill and care and with a due regard to each other. Thus the carder or comber, the spinner, the manufacturer, the dyer, and the finisher should each work with a sufficient knowledge of the bearing of his particular operation on the other processes of manufacture.

The high degree of specialization in the textile trade in some districts renders co-operation between the various branches specially necessary and at the same time specially difficult. This frequently causes great trouble to the dyer who may be merely instructed to match a given shade without being given information as to the processes which the material will afterwards undergo. This lack of information makes it impossible for him to select the most suitable method of dyeing to fit the conditions, and an

element of risk is introduced which is entirely unnecessary and should be eliminated.

Processes Preliminary to Dyeing.

In order that bright, clear, and fast colours may be produced in dyeing it is necessary that the textile material, whatever its character, should be thoroughly cleansed from all grease, dirt, and other impurities before the dyeing process is carried out. The treatment requisite for this varies. In the case of wool the cleansing process is known as "scouring," while the "bleaching" operation has a very similar object in the case of cotton, and silk is "boiled-off."

Wool Scouring.—Raw wool is naturally covered with a preservative greasy matter, termed "yolk," to which also adheres a considerable quantity of sand, dirt, and other foreign matter; the amount of pure wool varying from 30 to 80 per cent. of the weight of raw wool. The "scouring" or "washing" of raw wool has the object of removing these impurities, and the process is carried out by treating the wool with warm (not hot) solutions of soap with the addition of ammonia or carbonate of soda. This emulsifies the yolk, the sand, etc., being then readily washed away. Scoured wool is usually oiled before carding or combing, and this oil, together with dirt, etc., contracted during the various stages of manufacture, must be removed by a second scouring operation before yarn or piece dyeing.

Efficient scouring has a great influence on the dyer's work and on the final appearance and quality of the pieces. If wool is not properly scoured the colour is apt to be dull

and to "rub off," or may be uneven or show dark or light spots, bars or selvedges. On the other hand, if the scouring is too severe the fibre has a diminished lustre, a yellowish colour, and a harsh feel.

"Boiling-off" Silk.—This operation consists in treating the raw silk in (at least) two successive soap baths; the first one being used at a medium temperature, and the second boiling. It has the object of developing the lustre and soft feel of the silk by removing the "silk gum" with which the fibre is naturally encrusted. Silk may, however, be dyed "in the gum" or only partially boiled-off.

Cotton Bleaching.—The amount of impurity naturally present in raw cotton is small, but the raw fibre is not in a suitable state to be dyed, as the "cotton wax" present renders the fibre very non-absorbent. "Bleaching for white" is carried out by treating the raw cotton successively with boiling lime-water, boiling caustic soda, and cold dilute bleaching powder solution, with intermediate treatments with cold dilute acid and many washings. Goods which are to be dyed need not be treated with bleaching powder, excepting in the case of pale and delicate shades, but the earlier operations are always necessary.

Wool Dyeing Processes.

When a fabric entirely composed of wool is dyed in the piece it is obvious that a plain colour only can be obtained. If the design of the cloth includes differently coloured threads, the wool must be dyed before weaving, *e.g.*, as yarn; while certain effects (mixtures, etc.) can only be obtained by spinning together differently coloured *fibres* into the same yarn.

This last-mentioned case necessitates the dyeing of the wool in the form of sliver or of loose wool.

The form in which the wool is dyed (whether as loose wool, sliver, yarn, or cloth) greatly influences the choice of dyes to be used. Some dyes produce good, fast shades, but tend to dye unevenly; and such may be used for loose wool where any irregularity disappears in carding, spinning, etc., but are inadmissible in piece dyeing where absolute evenness of shade is essential. On the other hand, the cloth is not scoured after piece dyeing, and, therefore, dyes may be used which would be injured by the scouring process. Loose wool, however, must be dyed with dyes which will withstand scouring.

Dyeing of Loose Wool.—Loose wool may be dyed in square wood or stone vats heated by steam pipes, or in circular iron vats heated externally by fire. The wool must be stirred occasionally with poles to equalize the action of the dye liquor, but since this tends to felt it, discretion is necessary. Loose wool is now usually dyed by packing it into perforated receptacles which are either moved about in the hot liquor or through which the liquor is circulated by means of a pump. These newer mechanical processes are now largely used, as they leave the fibre in a free and open condition.

Slubbing (Sliver).—After carding or combing, the thin film of wool fibre is "condensed" into a ribbon of sliver, and may be dyed in this condition either in the form of hanks or wound into balls (tops). At this stage of yarn production the fibres have little coherence, and the hanks or tops require careful treatment. Tops are dyed in an apparatus in which mechanical circulation of the liquor is

provided for, but hanks of slubbing may be treated in the same way as yarn.

Yarn Dyeing.—Yarn may be dyed by hand or by machine. In the hand method the hanks are hung on sticks which rest across oblong vats containing the dye liquor. The hanks are systematically moved about in the liquor and pulled over the sticks. Dyeing machines are also largely employed, the hanks being mechanically moved about in the liquor, or the liquor mechanically circulated through the hanks.

Piece Dyeing.—In this case revolving rollers cause the pieces to travel through or move about in the dye liquors. The pieces run either at full breadth (dyeing in open width) or gathered together as a thick strand (dyeing in rope form), according to the nature of the material.

"**Woaded Colours.**"—This term implies that the wool has been dyed in the indigo vat. A woaded blue should be dyed with indigo alone, but in the case of woaded blacks, greens, and browns the indigo is necessarily combined with other dyes. The term has lost most of its significance since the introduction of the alizarin and other fast dyes.

Blacks on Wool.—*Logwood blacks* are very usual. The wool is mordanted with bichromate of potash and dyed with logwood in a separate bath, a small amount of yellow dye being used to neutralize the blue of the logwood. Beautiful blacks are thus produced, but they have the great defect of turning greenish during long wear of the material. *Alizarin blacks* are obtained by dyeing with a mixture of alizarin dyes or chrome mordant. They do not "green" in wear. Both logwood and alizarin blacks are fast to milling and scouring. *Acid-mordant blacks* (anthracene

acid black, diamond black, etc.) are dyed with the addition of acid and are afterwards chromed. They are fast to all influences. *Acid blacks*, such as naphthylamine and Victoria black, are dyed with the addition of sulphuric acid. They are fairly fast to light, but are not suitable for goods which are to be heavily milled.

Dark Blues, Greens, and Browns on Wool.—These may be obtained by using dyes of any of the various groups mentioned under blacks.

Bright Blues, Greens, Reds, Yellows, and Fancy Colours are chiefly dyed with acid dyes.

Cotton Dyeing Processes.

Cotton is mainly dyed in the form of hanks of yarn and warps, less usually as piece goods. The dyeing of cotton on spools or cops is now rapidly extending, two types of machines being in use. In one type the cops are placed on perforated or grooved skewers and the dye liquor forced through by a pump (skewer dyeing). In the other type the cops are closely packed in a tank, compressed, and the liquor forced completely through the whole mass (pack dyeing). In warp dyeing a number of warps pass side by side continuously through a series of vats containing the necessary mordanting or dyeing liquors.

Occasionally weft yarn is dyed in lengths, as in the case of warps the yarn being subsequently rewound on to weft bobbins. This cannot be recommended, as it is not unusual for warps to be somewhat darker in colour at one end than at the other, and when rewound this may produce a stripy effect in the piece. Cotton in the form of piece goods is dyed in the open width or rope form, usually the former.

The dyeing properties of cotton are quite different from those of wool, and therefore the processes and materials used in the two cases are to a large extent different. Cotton has little affinity for metallic mordants or for dyes belonging to the mordant, acid, or basic groups. It has, however, a definite affinity for tannic acid and for colouring matters belonging to the class known as "direct dyes." Cotton is dyed largely with this group, but the dyed colours, though bright and in some cases fast to light, are not fast to washing with soap. Many of these direct dyes are also affected by acids. A considerable number (but not all) of the direct dyes may be rendered satisfactorily fast by an after-treatment with metallic salts or by "diazotizing and developing," this applying principally to dark browns, blues, and blacks.

Fast Blacks on Cotton.—There are two ways of producing exceedingly fast blacks on cotton, viz., by dyeing it an "aniline black" or with a "sulphide black." Both are largely used, the latter chiefly for the warps of pieces which are afterwards "cross-dyed" (see Union Dyeing). Aniline black is somewhat more costly than a black produced by sulphide dyes, but is considered superior in body, tone, and brilliancy.

Fast Colours on Cotton.—Dark blues, browns, and greens, and a variety of greys, buffs, and pale fancy shades, are obtained by means of vat dyes (see p. 76) and sulphide dyes, but there is as yet no bright red belonging to these groups. The fastest bright red on cotton is Turkey red, which is obtained by oiling the cotton, then mordanting with alum and dyeing with alizarin. Para red (paranitraniline red) is also very bright and fairly fast. It is produced by saturating the cotton

with an alkaline solution of beta-naphthol, then drying and passing into a diazotized solution of paranitraniline. In this case, as in aniline black, the dye is actually formed on the fibre.

Cotton is also largely dyed with indigo in a similar manner to wool, but the vat is used cold and a chemical reducing agent is used (ferrous sulphate or sodium hydrosulphite).

Fast browns, drabs, etc., are largely dyed with catechu.

Basic Colours on Cotton.—These dyes are fixed on cotton by mordanting the fibre in a solution of some tannin matter (sumach or myrabolans), then "fixing" in a solution of some suitable metallic salt (tartar emetic or stannic chloride), and finally dyeing. The basic colours comprise a series of extremely bright reds, yellows, blues, greens, and violets, as well as many duller colours. As a class they are fugitive to light, but there are exceptions to this.

Dyeing of Mercerized Cotton.—The general dyeing properties of mercerized cotton are similar to those of ordinary cotton, but the affinity of mercerized cotton for the direct dyes, the sulphide dyes, indigo, and para red is much greater, and the shades obtained by using a certain strength of dye solution are much deeper and richer. On the other hand, mercerized cotton dyes less easily than ordinary cotton with basic colours. If the cotton has not been evenly mercerized it is impossible to produce level shades in dyeing.

Union Dyeing Processes.

Union goods composed of cotton and wool require special methods of dyeing. A common process is to dye the cotton

in the warp, the dyed cotton being then woven with undyed wool weft. The pieces are then "cross-dyed" with acid dyes which colour the wool only. The cotton warp must, of course, be dyed with colouring matters (such as the sulphide dyes) which are unaffected by boiling dilute acid. Another process largely made use of in low-class unions is to first dye the wool in the piece with acid dyes, and then to "fill up" the cotton by mordanting with tannin and dyeing with a basic colour, the whole of the cotton treatment being conducted in the cold in order to avoid staining the wool. When a uniform shade is required on both fibres the union material may be dyed with direct dyes which colour both wool and cotton.

Silk Dyeing Processes.

Silk is usually dyed in hank form; and closely associated with the dyeing is the so-called weighting process. Silk has the peculiar property of absorbing certain metallic salts and other bodies (tannin, glucose, etc.) to an enormous extent without injury to its lustre, and by suitable treatment it can in this manner be weighted to such a degree that 1 lb. of raw silk produces 2 to 3 lbs. of dyed and weighted silk. This weighting process is very general, 25 to 50 per cent. of added weight being usual. The practice is greatly to be deprecated when carried to excess, as it injures the wearing properties of the fibre. Pure silk has excellent lasting properties, but over-weighted silk will gradually become rotten merely by storage.

Wild Silk (Tussur Silk) is very difficult to dye, and a good black on tussur can only be produced by a few

dyers. It dyes readily with basic dyes and fairly well with acid dyes.

Reeled Silk (Mulberry Silk) has, generally speaking, similar dyeing properties to wool. It is chiefly dyed at about 80° C. with acid or basic dyes without mordant, and there is no difficulty in obtaining a variety of brilliant colours on this fibre. In boiling baths wool dyes deeper colours than silk, but at low temperatures the relative affinity is reversed, and an intermediate temperature may therefore be usually found (varying with each dye) at which the two fibres dye equally.

Silk is rarely dyed with indigo or with mordant dyes, excepting in the case of blacks.

The dyeing of black silk constitutes a special branch of the dyeing trade and needs considerable experience.

The Dyeing of Artificial Silk.

The artificial silks, being essentially constituted of cellulose, have dyeing properties[1] similar to those of cotton, but the various kinds of artificial silk differ considerably in this respect. On account of the low tensile strength of many artificial silks when wetted, great care is required in dyeing these fibres. They are best dyed at a comparatively low temperature with basic dyes (without mordant) or with direct dyes.

Colour Matching.

In dyeing any material to match a given shade great care is required to ensure that the two will match under all conditions. If the "matching off" is done by gaslight the two may be quite dissimilar when viewed by daylight. This

[1] See pp. 66–69.

well-known fact is due to the different optical properties of the various dyes. Two blue dyes, for example, may appear identical in hue, but when each is mixed with the same amount of the same yellow dye the resulting greens may differ considerably. If examined spectroscopically the two blue dyes will be found to have different absorption spectra, and this is the fundamental cause of their different behaviour in mixtures or when viewed in different lights. The special optical properties of the various dyestuffs are thus of great importance in "matching off" or dyeing to shade. Equally important is the character of the light by which the colours are viewed, and the light reflected from a white cloud into a window with a north aspect is considered the most suitable. The near presence of a red brick wall or any other coloured surface is quite sufficient to disturb an accurate match; direct sunlight or a deep blue sky being also fatal in matching certain greys, drabs, etc. The use of a perfectly uniform light of the same character as a north daylight thus greatly simplifies the accurate matching of colours.[1] The difficulties caused by the different absorption spectra of dyes can only be eliminated by a spectroscopical examination of each, or by using in bulk dyeing the same dyestuffs as were employed in dyeing the pattern which is being matched.

Fastness Properties of Dyes.

That some colours are "fast" and others are "fugitive" to light is a matter of as common knowledge as that some will withstand washing much better than others. These

[1] Such a light is to be found in the "Dalite" lamp of Dufton & Gardner.

differences are inherent to the nature of the dyes and are not (usually) due to defects in the methods of application. Thus the proper selection of dyes is of the greatest importance to the production of satisfactory results. It is obvious, for example, that material which is to be used for stuff curtains should be dyed with dyestuffs which have good fastness to light, fastness to washing being a secondary consideration; on the other hand, yarn which is to be used for making socks or underwear must be dyed with washing-fast colours, the effect of exposure to light being here less important. Again, in the case of woollen goods which are heavily fulled (milled), if yarn dyed the colours must be able to withstand that somewhat severe operation, and cotton warps which are made up with wool weft and then "piece dyed" must be dyed with colours which will not be affected by boiling dilute acid. Each case must thus be specially considered from this point of view as well as regards the question of producing the desired colour.

Tables have been drawn up showing the fastness properties of the various dyestuffs in regard to light milling, scouring, cross-dyeing, rubbing, washing, steaming, hot-pressing, etc., but it is impossible to usefully summarize such lists, and on this point manuals of dyeing must be consulted.

CHAPTER V

THE PRINCIPLES OF SPINNING

IT may seem somewhat out of order not to give priority to preparing and combing. But the end may justify the means.

Just as weaving naturally developed before spinning, so did spinning naturally develop before the many interesting and ingenious processes which to-day precede the spinning operation, rendering this operation much easier of accomplishment and vastly more perfect in its results than was the case in the olden days. In dealing with spinning prior to dealing with the preparatory processes, then, we are but following the historic evolution of the processes: and in so doing we have the great gain of knowing exactly what is required—what are the necessary conditions for a "good spin"—and can therefore more perfectly realize the *raison d'être* of the various processes to be subsequently dealt with and described. It might be contended that, following out this principle, weaving should be first dealt with. There is, however, a natural limit beyond which we may not pass without loss rather than gain.

Spinning may be defined as the art of throwing a number of more or less short fibres together in such a way that, being drawn out to form a comparatively fine filament, they grip one another by reason of the surface friction and the twist inserted, thus forming a comparatively firm, strong thread.

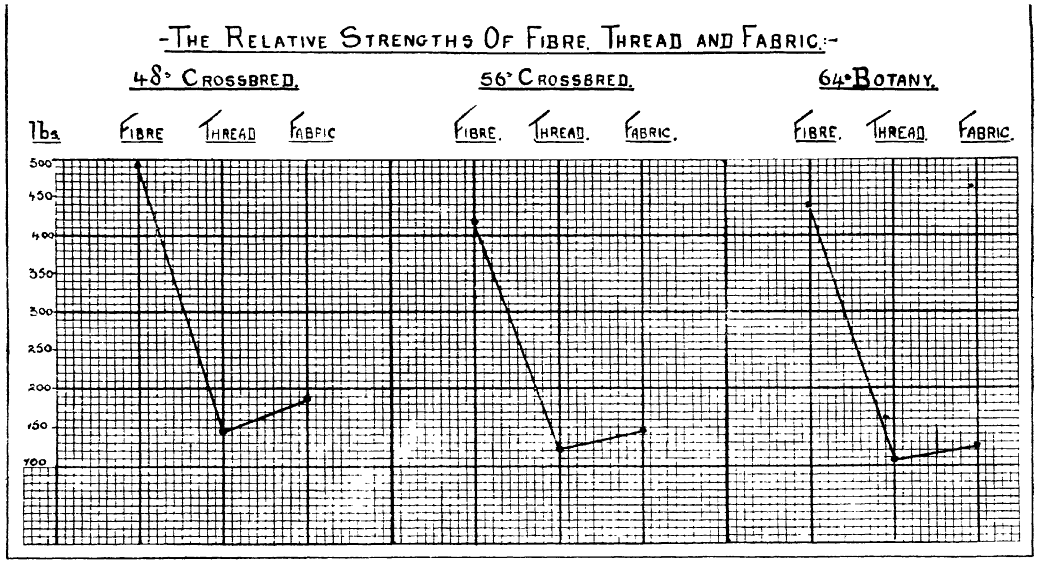

-The Relative Strengths Of Fibre, Thread and Fabric:-
48s Crossbred.
56s Crossbred.
64s Botany.
lbs.
Fibre
Thread
Fabric
Fibre.
Thread.
Fabric.
Fibre.
Thread.
Fabric.
500
450
400
350
300
250
200
150
100

Fig. 8a.

Thus spinning primarily consists of the two operations of drawing-out or "drafting," and twisting. It should at once be noted that "spinning" is quite distinct from silk "throwing," which simply consists of reeling the continuous thread or filament of from 400 to 1,600 yards forming the silkworm's cocoon, and throwing or twisting it with one or more threads or filaments of similar character to form a firm, stronger thread.

Long Fibre Spinning.—Very brief study of the art of spinning will demonstrate the comparative ease with which long fibres, such as flax, hemp, long wool, etc., may be spun into yarn. Given length and all else is simple. The early recognition of this fact would naturally lead to the preparation of flax, hemp, wool, etc., bundles or slivers so arranged that a continuous band of more or less parallel fibres might be passed into the spinning machine to be given the necessary twist and so be converted into thread. Thus the simplest and consequently earliest form of spinning would consist of some arrangement whereby, after having deftly formed a small band or sliver of fibres by the hand, twist might be expeditiously inserted. Such was "distaff spinning," the process being that just described, with very few conveniences for facilitating speed of production. How long the art of spinning rested in this very inefficient state we do not know, but probably for hundreds of years. Amid the ingenuity with which we of the twentieth century are surrounded from the cradle we cannot well gauge the mental effort necessary to evolve the idea of a continuous spinning process in place of the slow intermittent process. But it came at last, and the flax wheel, giving about three times the production, was evolved. In this the deftly extended sliver of right thickness and regularity was fed continuously by hand

into a flyer revolved by means of a foot treadle, which, in conjunction with the bobbin upon which the yarn was to be

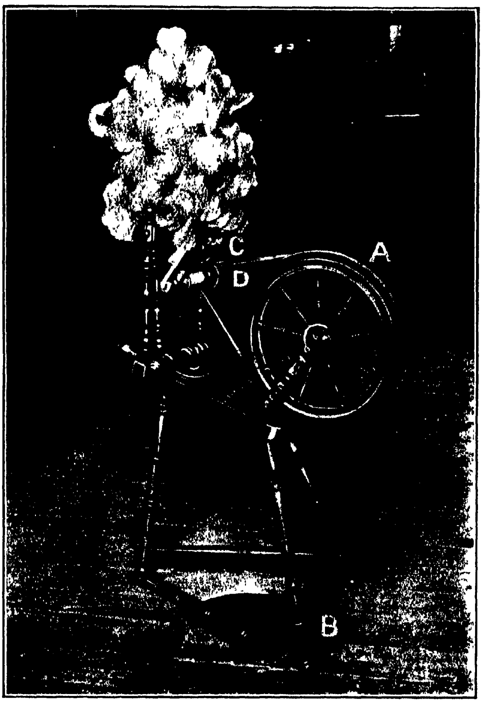


FIG. 9.—Double-grooved Wheel A; Pedal B; Flyer C; Bobbin D.

wound, both twisted it and wound it neatly upon this bobbin. No doubt the difficulty in evolving this arrangement was due to the fact that it is impossible to effect the continuous

feeding in and twisting of a sliver without some means *of winding on to the twisting spindle* the thread so formed, or, on the other hand, of winding the yarn continuously on to a bobbin without some arrangement for the continuous twisting of the same. The bobbin and flyer — practically the fundamental principle of all continuous spinning frames — is really a most ingenious arrangement, and it would not be surprising to find that short fibre spinning on the ordinary simple-spindle hand wheel really preceded this invention. The principle of long fibre spinning is infinitely simpler than the principle of short fibre spinning, but the necessary hand machine for continuous long fibre spinning is much more subtle and complicated than that required for short fibre spinning.

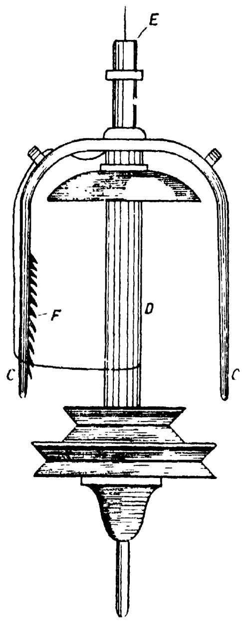


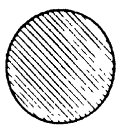
FIG. 9A. Diagram of Flyer and Bobbin arrangement on the ordinary Flax Wheel.

The "flax wheel" (Figs. 9 and 9a) consists of a double-grooved wheel (*A*), worked by a foot-pedal (*B*), round which two bands pass, one to the grooved flange on the spindle and flyer (*C*), and the other to the grooved flange of the bobbin (*D*), so that as the wheel is revolved by the foot-pedal it in turn revolves both flyer and bobbin. As the bobbin has a smaller grooved flange than

the grooved flange or driving wheel of the spindle, it therefore goes somewhat quicker than the spindle and flyer. The bundle of flax or wool is conveniently placed above the flyer and bobbin, and a convenient or required thickness of sliver is made up from it and passed through the eye (E) of the flyer, round the wing and over a notch or wire (F) which directs the thread on to the bobbin. Upon the wheel being revolved, twist is put into the sliver in proportion to the length of sliver delivered to a given number of revolutions of the flyer; and the yarn is wound up in proportion as the bobbin gains upon the flyer. *If no sliver were delivered and the wheel revolved, twist only would be put into the sliver. If all the sliver required were delivered, the bobbin held fast, and the flyer rotated, yarn would simply be wound upon the bobbin. The actual spinning operation comes in between these two extremes.*

The idea of increased production by a continuous employment of both hands and feet would naturally lead to further attempts at increasing production. It would at once be realized that two main developments were necessary, viz., a more speedy means of preparing the slivers to be spun and a greater number of spindles to be worked by hand. This latter idea probably germinated first, as we have fairly early records of a double-spindle flax wheel. Few people, however, would be skilful enough to work this with the condition of feeding the spindles with unprepared slivers; hence little advance was made. The development of drafting rollers by Lewis Paul eventually entirely removed this limitation. How crude the ideas of the eighteenth century were we can only realize by again reverting to the fact that it was supposed that, as with metals, one pair of

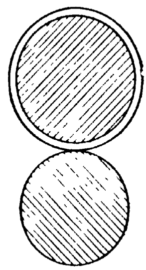
Single Roller.



Points for Consideration.

(1) Size.
(2) Material (foundation and covering).
(3) Fluting.

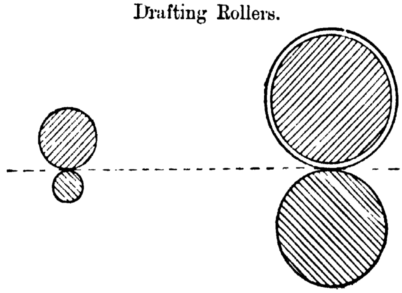
Double Rollers.



Points for Consideration.

(1) Sizes and Relative Sizes.
(2) Material (foundations and coverings).
(3) Fluting.
(4) Method of Weighting.
(5) Method of Driving.

Drafting Rollers.



Points for Consideration.

(1) Relative Sizes of Back and Front Rollers.
(2) Materials (foundations and coverings).
(3) Flutings.
(4) Method of Weighting and Influence on Power Consumed.
(5) Distance apart.
(6) Method of Driving.
(7) Relative Speeds of the two pairs of Rollers.
(8) Inclination of Rollers.
(9) Supports (carriers) between the two pairs of Rollers.

Fig. 10.

rollers would be sufficient to effect the necessary drafting. The development, however, was made, and its utility gradually realized to the full. We can well imagine the interest that Lewis Paul, Arkwright, and others would have in experimenting with rollers and noting the conditions under which they might best be employed for drafting, and it is something to their credit to be able to say that these early workers practically developed in their machines principles and methods which we have not been able to improve upon in principle to any great extent.

A few words on roller-draft will demonstrate the principles employed. Some of the factors of roller-draft are illustrated in Fig. 10. These factors seem comparatively simple, but they are not really so. Take for example the first factor—size of rollers. At least three varying factors are here involved, viz., length of fibre to be drawn, size of roller to give the best conditions of wearing surface, and exact condition of gripping of the fibre desired. Thus in the spinning of short fibres such as cotton the diameter of the rollers should be approximately the length of the fibre (Fig. 11), while in long wool fibres (Fig. 12) there is little relationship of the diameters of the rollers to the length of the fibres, but on the other hand these diameters are decided with reference to grip on the fibre and surface wearing quality. For a $1\frac{1}{2}$-inch staple cotton a $1\frac{5}{8}$-inch diameter pair of rollers is usually employed, while for an 8-inch wool yarn a $2\frac{1}{2}$-inch top back roller bearing upon a $1\frac{1}{2}$-inch diameter bottom back roller and a 5-inch top front roller bearing upon a 4-inch diameter bottom roller are usually employed. Here again it will be noted there is an interesting question of "grip." With small rollers the gripping

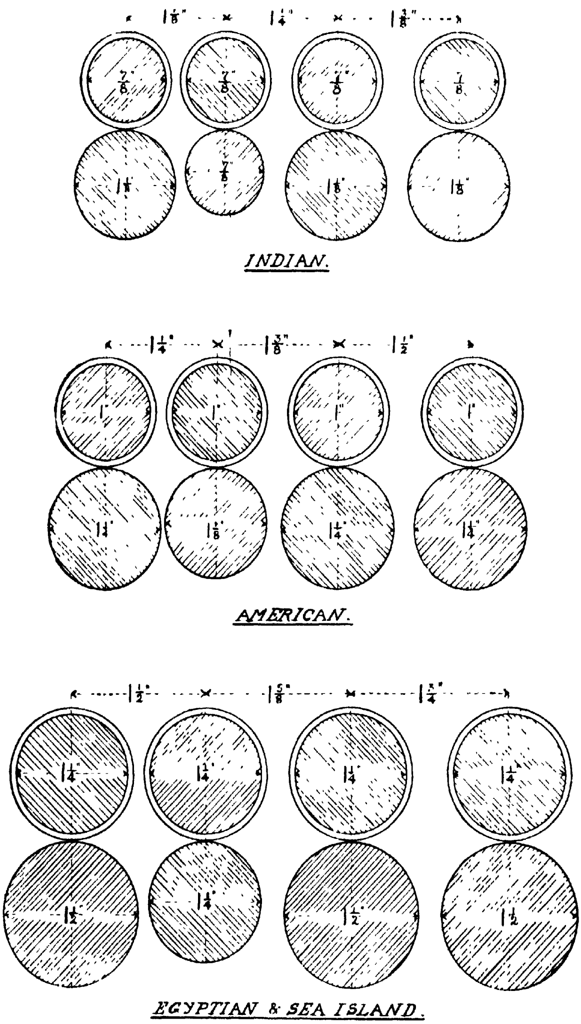


FIG. 11.—Drafting Rollers for Various Lengths of Staples of Cotton

surface will be small, and consequently there is a tendency to "cut." With larger rollers the gripping surface will be much larger, and consequently a firmer grip obtained with less fear of cutting. It will further be evident that it may be very desirable to leave some rollers bare and to clothe other rollers

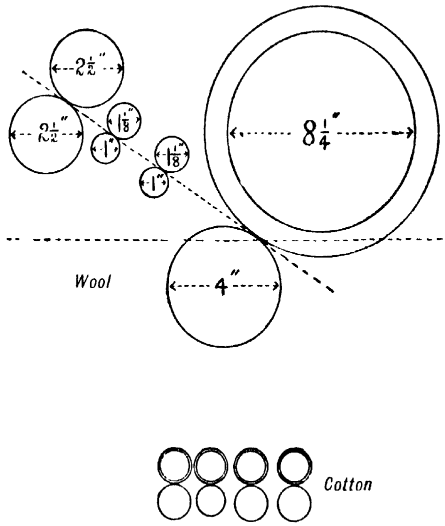


FIG. 12.—Illustrating the Relative Sizes of Wool and Cotton Drafting Rollers.

with leather, etc. Now, iron rollers may be clothed with leather in two ways, first by running a continuous leather apron between them, or by actually clothing one of the rollers with leather upon a felt or other foundation. Corresponding fluting necessitating rollers of equal size renders the leather apron idea more economical, and in fact necessary, in certain

wool boxes, while in other boxes and frames a large 6-inch roller, leather clothed, fulfils the requirements of the case both from the efficiency and wearing surface or cost points of view.

Again the questions of double metal nip, metal and leather or cloth nip, or double leather or cloth nip are worthy of the most careful consideration. One of the rollers in a wash-bowl is clothed with wool and wool grips wool against metal. But in the case of cotton, leather against metal is applied. Here is a most interesting problem.

Then with reference to the distance apart of the two pairs of drafting rollers most interesting points are to be studied. Take, for instance, an 8-inch wool fibre. If this is passed through rollers 6 inches apart—the front rollers revolving faster than the back rollers—it will probably be broken. If the rollers are exactly 8 inches apart the back pair will give it up just as the front pair take control of it; while if the rollers are, say, 10 inches apart each fibre must freely ride upon its neighbours for 2 inches after leaving the back rollers before the front rollers take it. The middle condition is the correct one, all cotton drawing rollers being very accurately set to control the fibre as positively as possible without breaking it. But in a well-prepared wool combed sliver or " top " the fibres may vary from 4 inches to 10 inches or 12 inches, while there is also the question of twist in the sliver to be taken into account, twist enabling the drawer, as it were, to control the fibre with the fibre. If it were not for the twist factor and the natural cohesion of wool—save when affected with electricity—wool " top " drawing would be a much more difficult process than it actually is; in fact it would be necessary to work to the shortest fibre, breaking all the longer fibres, thus

consuming power and destroying the quality of length so often required in worsted yarns.

An economical question is involved in the speed at which

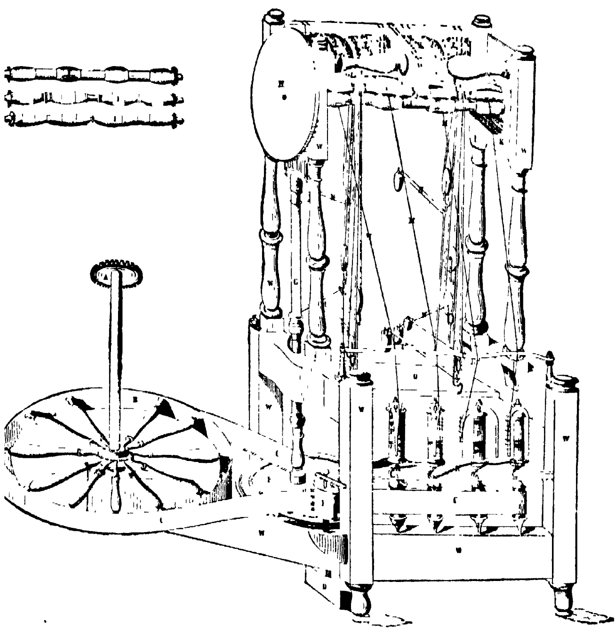


FIG. 13.—Arkwright's Water-frame.

drafting rollers should be run. Alone, *i.e.*, without any spindle attachment to twist and wind-up the sliver drafted, the limit would depend in part on the nature of the fibre. Cotton, for example, can be drafted quickly when the fibres are once started sliding upon one another, *but not before*; and

again, air blasts and air friction so affect cotton that they must be very carefully taken into account. There is also a mechanical problem of wear and tear involved, so that altogether this also is really a most interesting, if somewhat involved, question.

It will now be realized that given drawing rollers, the flyer and bobbin mechanism, and a reasonably steady driving power, the factors for a successful automatic machine are present. Richard Arkwright was the first to recognize this, and his water-frame was the first machine of any moment effecting the spinning of yarns automatically.

The illustration of Arkwright's "water-frame" (Fig. 13) will explain the general arrangement. The only new problem involved is the relationship of front rollers and spindle. The possible positions of spindle to front rollers are illustrated in Fig. 14, but it should be further remarked that the solution of this problem will in part depend upon the inclination of the drawing rollers. It should further be remarked that probably "gravity" cannot be entirely ignored. So far as relative position goes the relationships shown at *A* and *E* are identical, but it will be realized at once that the force of gravity may make a material difference in the "spin," especially if the sliver is heavy and has not marked adhesive qualities. The main point to note, however, is that of limitation of the twist. Anything touching the yarn between the top of spindle and the nip of the front rollers may limit the twist to below this point. Thus in some cases it may be desirable to have such a relative position of spindles and front rollers that the twist runs right up to the nip of the rollers; in other

cases it may be desirable to lay the sliver on the bottom front roller; and in other cases it may actually be neces-

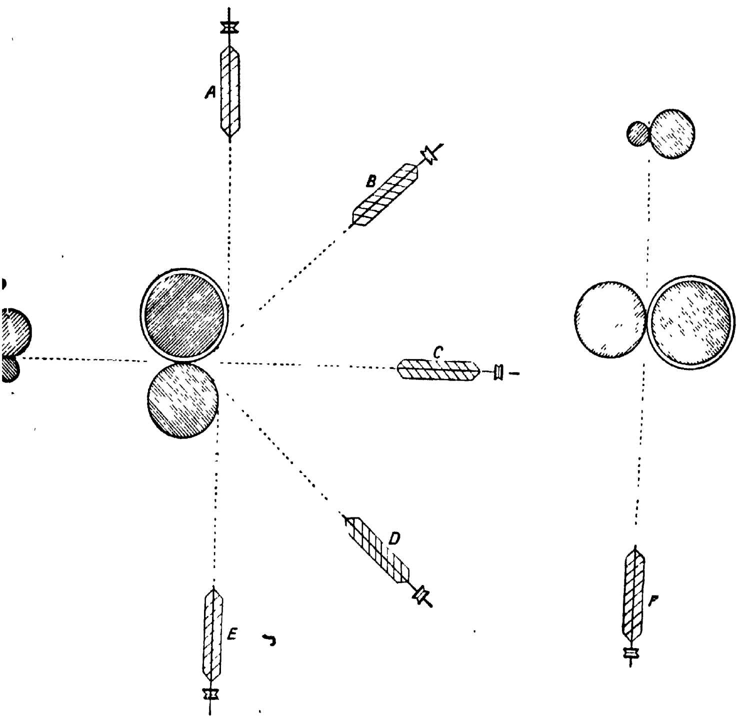


FIG. 14.—Possible position of Spindle in relationship to Drafting Rollers.

sary to introduce what is known as a trap-board with the threefold object of carrying the yarn straight from the nip of the rollers, of centring the yarn above the spindle—as in the cap frame—and of holding the twist in the yarn

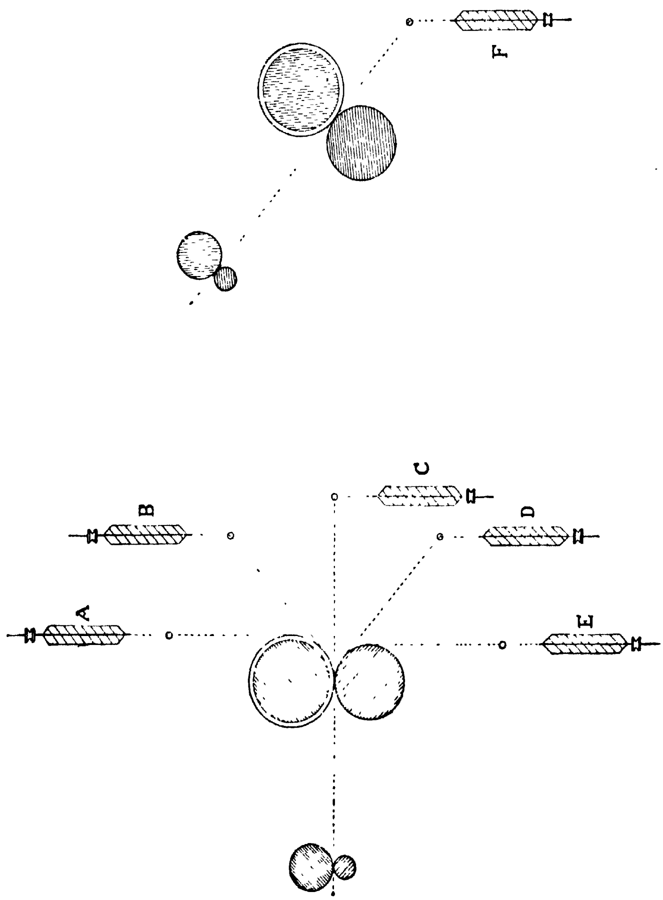


Fig. 14a.—Possible position of Spindle with Guide Eye in relationship to Drafting Rollers

near to the spindle or cop. This latter point is worthy of very careful consideration, as the holding apart of two threads to be twisted together just above the twisting spindle has a marked effect on the regularity of the twist. The inclination of the spindle also, as will be noted directly, is most important in the woollen mule, and in general hardly receives the attention it merits.

A glance may now be taken at the modifications of the continuous bobbin and flyer principle of spinning introduced since the time of Arkwright.

When it was realized that the bobbin or spindle was the spinning mechanism and the flyer the winder-on, an endeavour was naturally made to simplify this latter, thereby saving expense in construction, effecting a reduction in the consumption of power, easier doffing and quicker running. The labour difficulties in America further forwarded this movement and so the ring frame came into being.

In the modern ring frame the spindle—but in this case without a flyer—is the chief motive factor. The drafted sliver is delivered exactly above the centre of the spindle, so that upon the spindle being revolved twist is put into the sliver. But how is winding-on effected? Surrounding the spindle is the ring—or, conversely, the spindle passes exactly through the centre of the ring, and upon this ring, suitably controlled by the ring-flange, is a "traveller." The sliver, instead of passing directly to the apex of the spindle, first passes through the traveller and then on to the spindle or bobbin placed on the spindle. The traveller thus acts as a retarder, enabling the spindle to wind up the yarn delivered to it by the front rollers. The yarn is distributed on to the

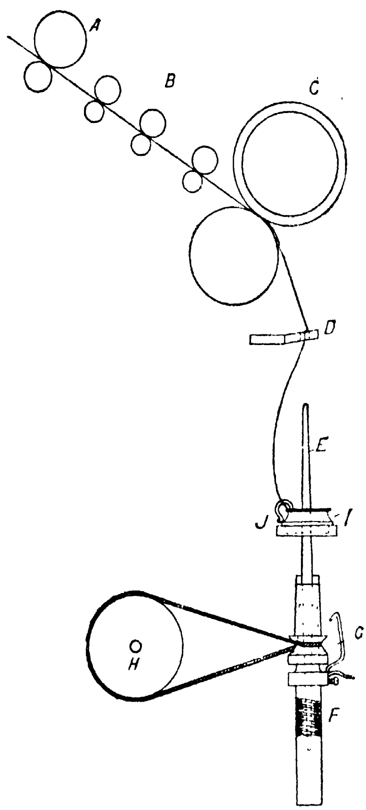


FIG. 15.—Ring Spring Frame.—*A*, back rollers; *B*, carriers; *C*, front rollers; *D*, eyelet board; *E*, spindle; *F*, spindle support; *G*, spindle wharl; *H*, tin drum round which spindle band passes; *I*, ring; *J*, traveller.

bobbin by the slow movement up and down of the ring-rail, the spindles naturally being fixtures. To ensure high speeds on this machine—say 7,000 to 12,000 revolutions—many spindles of special construction have been designed, some self-balancing, some running in oil, etc. (see Fig. 15).

The development of the ring frame would naturally lead inventors still further afield, and eventually the cap frame was evolved.

The cap frame is very similar to the ring frame, save that the edge of the cap itself develops, or helps to develop, the air friction whereby the bobbin may wind yarn on to itself. As the caps are too heavy to move, and as the distance between the trap-board *D* and the edge of the cap should be constant, the bobbin-rail moves to effect the distribution of the yarn on the bobbin (see Fig. 16). When the cap frame was first tried in Bradford the yarn was so softly wound that it could be jerked off the bobbin. This was owing to the fact that the frame was run at 2,800 revolutions per minute "to give it a chance." It was only when the frame was speeded up to 5,000 revolutions per minute that its great possibilities were realized. The cap frame came into the wool district from the cotton district. Why it should be so successful for pure Botany wool and so useless for cotton is again a most interesting question which we have not space to investigate here.

In two important points the supposed automatic spinning frames are not automatic. They neither feed themselves automatically nor do they "doff" themselves automatically. The comparatively large bobbins placed in the creel behind the back rollers of a spinning frame contain so much sliver to be spun that little manual labour is necessary

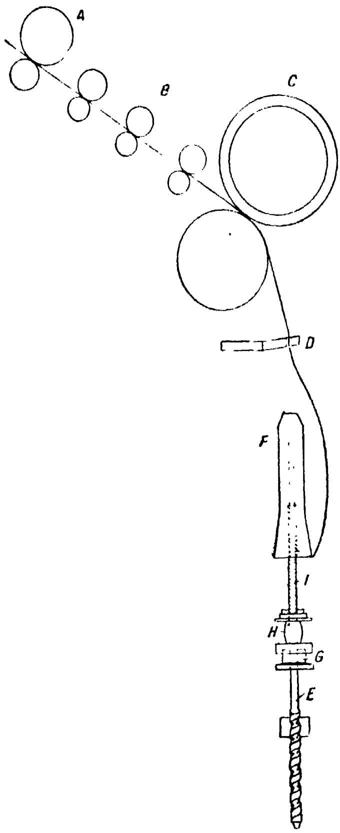


FIG. 16.—Cap Spinning Frame.—*A*, back rollers; *B*, carriers; *C*, front rollers; *D*, eyelet board; *E*, spindle fixed in framework; *F*, cap supported by spindle; *G*, bearing for tube *I*; *H*, wharl round which driving tape passes; *I*, tube upon which bobbin or spool is fixed and carried round.

to keep the frame supplied with slivers or roving to be spun into yarn. Very different is it, however, with the doffing of the comparatively small spools or bobbins upon which the spun yarn is delivered. On an average a flyer frame running on $\frac{1}{10}$'s with 10 turns per inch, will be doffed six times per day of $10\frac{1}{2}$ hours, and a cap frame running on $\frac{1}{48}$'s with 16 turns per inch seven times per day of $10\frac{1}{2}$ hours. With the scarcity in half-time labour the invention of an automatic doffing motion has become imperatively necessary. Messrs. Clough & Co., of Keighley, first successfully employed such a motion on their flyer spinning frames, while Mr. W. H. Arnold-Forster, of Burley-in-Wharfedale, quickly followed with a top-driven flyer automatic doffing frame. Then came several attempts to "doff" the cap frame; and finally it is fair to say that Messrs. Prince, Smith & Son and Messrs. Hall and Stell, both of Keighley, have each placed on the market successful flyer and cap doffing mechanism. At first it was thought that given half-time labour such a motion was not required from the economical point of view. From experiments recently made, however, it would appear that it is more than probable that the doffing motion will ultimately supplant half-time labour, being actually considerably more efficient with regard to output. This, however, refers more particularly to flyer frames—the conditions of doffing cap and ring frames being somewhat more complicated. Considering the mechanical problem in a broad way it would seem as though the mechanical problems of doffing are greater than the problems involved in spinning, and that therefore the spinning machine should be made to the doffer and not, as at present, the doffer applied to a machine designed without regard to any such attachment. Of course, to change a machine which, although apparently

simple, has been evolved by generations of workers and probably contains more than we have the least idea of, is a dangerous thing. Still, the result may justify the attempt.

Short Fibre Spinning.—The art of short-fibre spinning would possibly develop some time after long-fibre spinning, being somewhat more involved and of such a nature that it would not so readily be "thought of," but would probably be accidentally "discovered." Briefly, the art of short-fibre spinning consists in supporting the thread or sliver *during elongation* with twist instead of with rollers. Did spinning simply consist of *twisting* fibres together, then it would be impossible to differentiate between long-fibre spinning and short-fibre spinning. Any difference would then probably lie in the preparation of the respective fibres for the spinning. But the drafting or drawing out of the sliver being necessarily implied, at once emphasizes the difference between long- and short-fibre spinning. For in long-fibre spinning the fibres are of such a length and are arranged so parallel in the sliver that when the spinning twist is inserted it is inserted into a sliver or thread already formed, and of which the thickness is already decided. Whereas in short-fibre spinning the commencement of the final twisting is really a putting in of drafting-twist, *i.e.*, as the twist is inserted the sliver is elongated. But for this drafting-twist the short-fibred slivers to be spun would break. This drafting-twist running into the thinnest sections of the slivers strengthens them, and these becoming the strongest sections in turn serve as a means to draft the sections which are now relatively weaker. Upon the drafting being completed the elongated sliver is then converted into a true thread by receiving its final complement of twist. So potent is the drafting-twist that it must be exactly adjusted to the

length of fibre being spun, the shorter the fibre and the more drafting-twist, and conversely, the longer the fibre the less drafting-twist, until for long fibres no twist at all is possible, as they bind the sliver too much, under which circumstance roller control must be resorted to. The

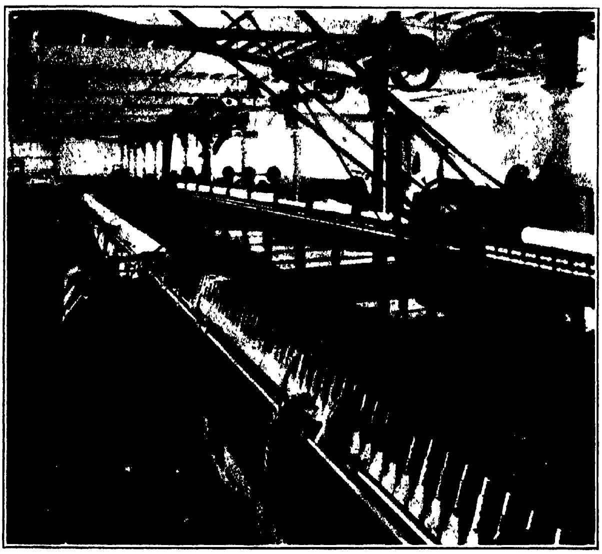


FIG. 17.—General View of Woollen Mule.

principle of spindle-draft is the distinguishing feature of mule spinning, especially woollen mule spinning, producing marked characteristics which in turn have a fluence in both the weaving and fi Again, the method of inserting twi on a mule must have some influence

the resultant yarn, though what it exactly is we cannot yet say.

The woollen mule was led up to by the jenny (Fig. 18), which was simply an enlarged single-bobbin wheel arranged to control from sixteen to sixty spindles. A similar machine, termed a billey, was introduced between the card and the jenny, to prepare the slivers for their final elongation. Both machines acted on the principle of "spindle-draft."

FIG. 18.—Hargreave's Spinning Jenny.

The woollen mule is the perfect short-fibre spinner. In brief, a woollen mule consists of three main parts, viz., the prepared or condensed sliver holder and deliverer, the carriage with its spindles, and the headstock which controls the action of the other two. The condensed sliver (A, Fig. 19), brought up from the carding machine on lightly-flanged long condenser bobbins, rests on a delivery roller, and being turned by surface completct is always completely under control. The slivers from thread lcondenser bobbins are passed through a pair of stationary is the rs the revolution of which is in accord with the turning

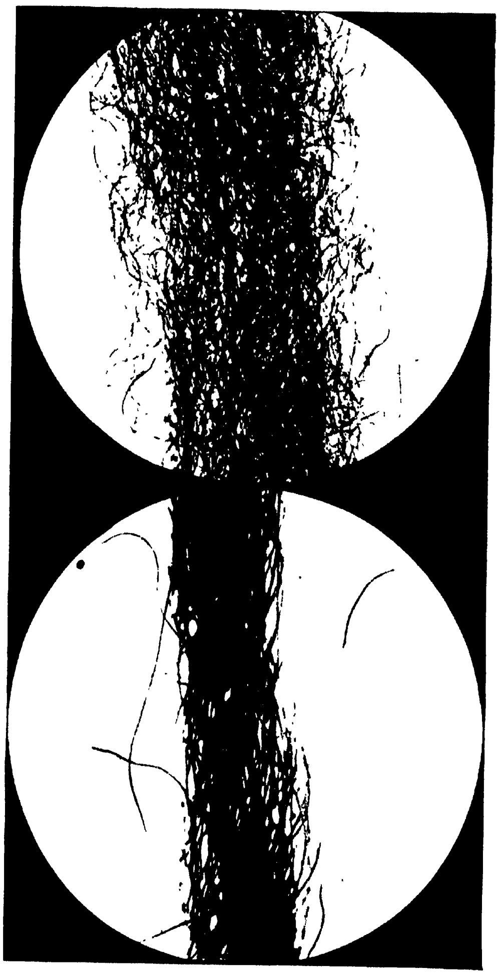


FIG. 19.—(*A*) Condensed woollen sliver, prior to spinning; (*B*) condensed worsted sliver prior to spinning.

of the condensed sliver roller, and both are under perfect control from the headstock, intermittent delivery being varied at will according to the requirements presently to be described. The carriage—carrying from 300 to 700 spindles of any suitable pitch, thickness and inclination, according to the work to be done—is perfectly controlled from the headstock by means of drawing-out and running-in scrolls. The speed of the spindles is also under perfect control so far as drafting-twist and final twist are concerned, and something more than under perfect control when the building up of the cop is in process, as will be explained immediately. One complete spin—starting with the carriage run-in to the delivery rollers, and consequently with the spindle points close to the grip of the rollers, from which the condensed sliver passes direct to the spindle points takes a few turns round the spindle and in the shape of spun yarn forms the cop on the spindle—may be described as follows: As the delivery rollers deliver condensed sliver the carriage with its spindles slowly retreats until it reaches about half the distance of its complete traverse, when the delivery rollers suddenly stop. The carriage, however, goes on towards its full traverse slower and slower, in the meantime the spindles putting in just the requisite drafting or supporting twist which, owing to the nearly upright position and thickness of the spindles, vibrates right along the slivers and ensures distribution in fair proportion to the diameter of the yarn, so that as thin places are strengthened and become strong the thick places are drafted out, and so an equalizing action goes on right throughout the drafting operation. Upon the carriage reaching the extent of its traverse—when drafting is completed—the spindles are turned on to double speed to effect the necessary twisting of the approximately two yards

of yarn per spindle, just twisting as quickly as possible. The insertion of so much twist naturally causes a contraction of the thread, and to allow for this a slight return of the carriage towards the delivery rollers is arranged for or a slight additional delivery of condensed sliver made. Upon the completion of

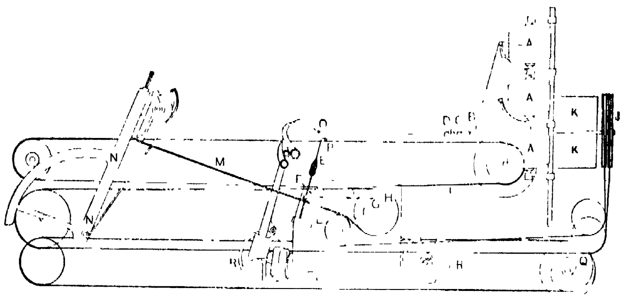


FIG. 20.—Worsted Mule Section. A, A_1, A_2, French drawn rovings ready for spinning; B, jack drafting rollers; C, carriers; D, front drafting rollers; E, spindle carrying spun yarn; F, wharl on spindle from which band passes to tin drum G; H, drum which conveys motion through the cord I, from the twist pulley J, in the headstock K, to tin drum G; L, a catch scroll which receiving a variable motion from the quadrant NN, through the chain M, gives the spindles the correct rotation to wind up the yarn for building a firm cop during the running in of the carriage at the same time that the faller wire O and counter-faller wire P direct and tension the winding up of the yarn, this being further controlled by the action of the "copping plate," which controls the up and down movement of the faller wires.

the twisting the spindles are reversed for a few turns—this is termed "backing-off"—to enable the faller guide wire to commence building up the cop from where it left off at the last run-in, and a counter-faller wire, suitably weighted, rises, as a perfectly even tension must be maintained on the yarn, otherwise it "snarls" and forms kinks. The carriage is now freed and commences its run-in under the control of

scrolls which, working in conjunction with a quadrant which controls the turning of the spindles, and a "copping-plate" which controls the traversing of the faller-wire, result in a firm, sound cop being built up. Upon reaching the delivering rollers the faller-wire rises; the counter-faller wire falls and the spindles are free to repeat the cycle of evolutions. Of course a greater or less amount of condensed sliver may be delivered, according to the draft required, more or less drafting-twist may be inserted in accordance with the binding qualities of the material being treated, the exact turns per inch required may be inserted at double speed, and by a change of "copping-plate" the yarn may be wound on bobbins instead of on paper tubes.

From this description the two main features of mule-spinning, viz., the spindle-draft and the twisting of unsupported threads will be fully realized. It should be noted, however, that as previously remarked the machine just described should not be called a mule, for Crompton's "mule" received its name from being a hybrid combination of roller and spindle-drafting, while in the Woollen mule there never has been any roller-draft; it is simply an automatic jenny in the "billy" form.[1] The cotton and worsted mules, however, are genuine mules, as roller-draft in these plays almost a leading part. If, as very often happens, little or no spindle-draft is inserted by these mules the only possible advantage would appear to be in the method of inserting the twist. Against this presumable advantage there is the intermittent character of the cycle of spinning operations and the additional floor space occupied to be placed. That there must be an advantage is evident from the fact that mule spinning in the cotton trade at least holds its own, while in

the case of the worsted it is rapidly making headway. In both these cases it may be that it is the peculiar method of sliver preparation, which it makes possible, which is the real advantage. This will claim attention in the next chapter.

It will have been noticed that although cotton is short fibred, nevertheless it is frequently spun on the roller-draft or long-fibre spinning method. This is accounted for by the nature of the cotton fibre, which is much more docile than wool and does not require length to control it, but may readily be controlled by small drafting-rollers. In this connection it is interesting to note that prior to the mechanical era cotton yarns were probably spun very largely, if not entirely, upon the short-fibre spinning system. This is borne out by a knowledge of the cotton industry in India, in which the flax wheel plays no part, all the spinning being done on the simple-spindle wheel. This rendered cotton spinning a relatively difficult process as compared with either linen or long wool spinning; hence the comparatively small number of people engaged in the industry prior to the mechanical era. But the introduction of the various automatic drawing and spinning machines rendered possible the drawing and spinning of cotton on the long-fibre principle; in fact it is practically true to say that the cotton industry is a machine-created industry. It would probably always have remained small but for the introduction of mechanical methods. It would also be interesting to investigate to what extent the short or Botany

[1] It is an interesting problem in economy of power to decide whether the spun yarn should be run backwards or forwards and the condensed sliver left stationary or *vice versâ*. Both forms are still in use to-day.

wool industry is a machine-created industry. It is true that woollen yarns were spun from short wools prior to the mechanical era, but the short wool worsted yarn is evidently a creation of the mechanical era; and consequently to this mechanical development must the large demand for Botany wools be attributed. That this is so is proved by the fact that the largest increases in the production of these yarns have taken place since the perfecting of the necessary preparatory machinery and the machine wool comb specially adapted for short wool combing, *i.e.*, between 1840 and 1880; although short Botany wools were previously largely employed in the clothing and woollen trade.

During the past twenty-five or thirty years many endeavours have been made to produce a frame yielding yarn possessing the same characteristics as yarn spun upon the mule. If such a frame could be produced a great saving in space and a markedly increased output would be effected, since such a frame would be a continuous spinner, whereas the mule is an intermittent spinner. The difficulties to be faced are principally these:—Firstly, the continuous drafting of the sliver along with the insertion of the necessary drafting-twist; secondly, the insertion of the true thread twist; thirdly, the construction of a frame as easy to follow—to piecen up broken ends on—as the mule; and fourthly, a frame as inexpensive in both initial cost and in "following" as the mule. One of the first attempts was that made by Celestin Martin, of Verviers, in which a "twizzler" to insert false drafting-twist is placed between two pairs of drafting rollers, and a ring-frame arrangement placed to receive, twist and form a cop of the drafted but twistless yarn as delivered by the second pair of rollers.

This machine, although employed to a considerable extent on the Continent, cannot be considered entirely satisfactory. The drafting being effected or supported by false twist is very different in character from that obtaining on the mule. Again, the vibration which runs along the thread in mule spinning owing to the thickness and inclination of the spindles is not attempted here. Again, the final twisting conditions obtaining on the mule do not in the least obtain here; and finally, the difficulties of piecening up are greater.

In Fig. 21 the latest style of mule-frame is shown. In this it will be noted that the "twizzle" (*B*) is placed practically upright and has two projections upon it. These are to give the "vibration" or short pulls to the thread which no doubt play such an important part in spindle-drafting on the mule. This form of twizzle, however, obviously increases the difficulties of piecening up. Arrangements are also made in this machine to make the drafting intermittent, but the twisting and winding on to the bobbin are continuous. As the main point in production lies in the twisting, this appears to be a move in the right direction. The conditions of final twisting, however, are similar to those employed in the Celestin Martin frame, and will probably result in a different yarn being produced as compared with the genuine mule-spun yarn. Considering the economic effect in the space occupied and the possibly greater production owing to the continuous action of the frame, this frame may be wisely and economically employed for the spinning of the harder twisted woollen yarns, although its initial cost per spindle will probably be much greater than the mule.

In another frame of a similar style bars are inserted between

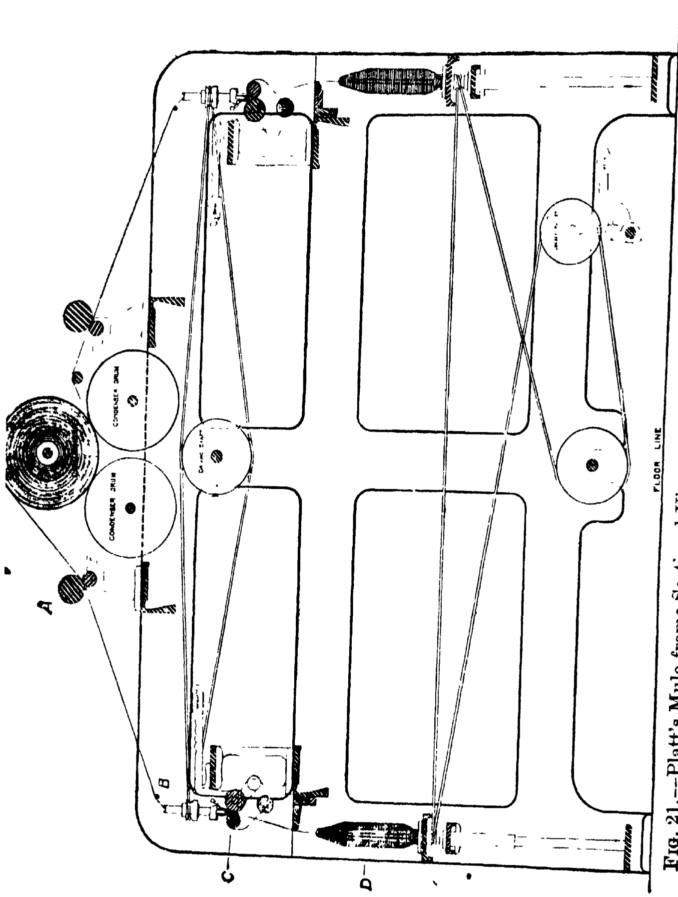


FIG. 21.—Platt's Mule-frame Sectional View. *A*, first drafting rollers; *B*, lugged twister; *C*, second drafting rollers; *D*, ring spinning frame.

the back and front rollers, near to the back rollers, with the idea of limiting the "run-up" of the twist in the thread, so that drafting may be more readily effected. This, however, shows a total want of perception as to the fundamental principles of spindle-draft.

Again the difficulty was supposed to be solved by the addition of an apparatus to the condenser, which took the slivers directly from the ring doffer—thus obtaining a "free-end"—and twisted them into what were called threads. As there was no draft at all in this case the resultant strands were simply twisted slivers and not spun threads.

In still another type the front drafting rollers were lifted to allow the twist to run up to the back rollers.

From these attempts it would appear that for the spinning of characteristic woollen yarns—especially fine yarns with much twist—the woollen mule is not at all likely to be superseded.

* * * * *

All the foregoing particulars should lead up to a thorough apprehension of the conditions governing yarn and thread construction. Actual thread structures must now be considered. These may well be studied under two headings, viz., single yarns and two- or many-fold yarns. Perhaps a third class should be added of fancy yarns, which, however, can only be referred to very briefly in a treatise of this nature.

Single yarns are apparently so simple in fibre arrangement that it would seem that there is little to be noted about them. The difference in fibre arrangement between woollen and worsted yarns must certainly be noted, and even in worsted yarns the question of fibre length and binding must be carefully considered.

Undoubtedly the next most important matter is the twist. This is usually defined in "turns per inch," but

the designation by "angle of twist" is so much more useful and satisfying that it is here adopted as the basis of treatment. With reference to both single and two-fold yarns the following formulæ will be found to be of great practical utility:—

If D = the diameter reciprocal,

π = ratio of circumference to diameter,

θ = angle of twist, and

T = turns per inch, then

$$\frac{D}{\pi \times \cot \theta} = T \text{ and } \frac{D}{\pi \times T} = \cot \text{ of } \theta.$$

In single yarns the "fibre angle" is dealt with; this has an important bearing on the folding of yarns. In all two-fold yarns the relationships of "fibre angle" and "twist angle" must be carefully considered. Thus, as illustrated in Fig. 22, the three most ordinary relationships will be:—

Converse twist (2).
Straight-fibre twist (1).
Concurrent twist (3).

Of these, converse twist is often spoken of as "balance twist," since the torsional strains due to the single twist may be just balanced by the torsional strains due to the two-folding twist.

In "straight-fibre twist" the two-folding in the reverse direction to the single twisting just brings the fibre direction into line with the longitudinal direction of the thread. The conditions for obtaining this relationship, which is certainly one of the best possible, is:

$$\frac{S}{\sqrt{2}} \text{ of two-folding, } \frac{S}{\sqrt{3}} \text{ for three-folding,}$$

$$\frac{S}{\sqrt{4}} \text{ for four-folding, etc., etc.,}$$

where S = turns per inch in the single yarn.

Concurrent twist used to be much more extensively employed than at present, owing to the mistaken idea that to put into the two-fold the same number of turns per inch put into the

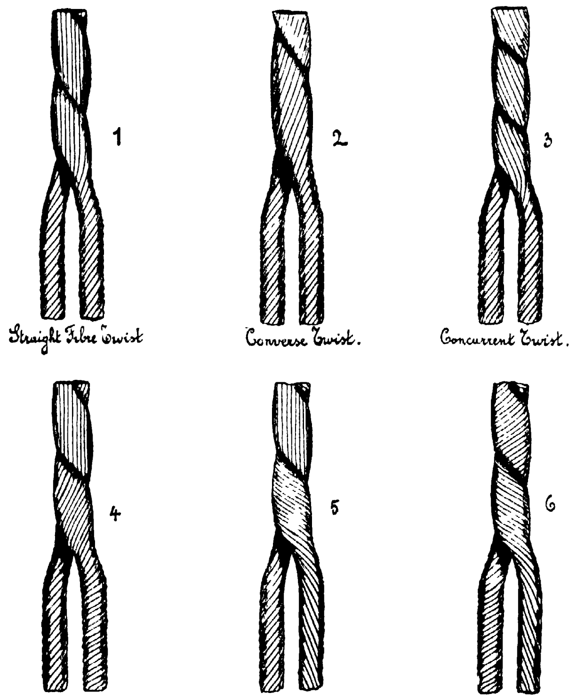


FIG. 22.—Six Classes of Two-fold Yarns.

single, but in the reverse direction, would just take out the single twist and make the softest possible yarn.

The three other possible conditions for two-fold yarns are shown in Fig. 22 (4, 5 and 6). Each of these yarns has special

properties, which should be fully realized by the yarn and cloth constructor. For voile fabrics, for example, (6) is most useful.

Fancy yarns may be classed as knickers, cloud, knop and loop, there being several varieties of each. From time to time fashion favours the fabrics into which these yarns may be woven, but generally these yarns have only a limited application.

CHAPTER VI

PROCESSES PREPARATORY TO SPINNING

In the foregoing chapter the various principles of spinning have been fully considered on the supposition that both long and short fibres of various classes were available for spinning. No account, however, was taken of the fact that in no case, with the partial exception of silk, are either the long or short fibres of commerce found naturally in a condition suitable for being spun into yarn. For example, the variation in length in most materials necessitates a combing operation to classify the fibres which may be satisfactorily spun together, long spinning well with long, and short with short, but not long with short. Again, all materials contain either impurities natural to their growth or accidental impurities which get into the mass of fibres and must be removed before spinning can be attempted. In the first class the cortical substance in flax, the gums in China-grass, the yolk in wool, the gum in silk and the seeds in cotton, may be cited. In the second class water, beyond a certain amount, in flax, wool, and cotton; and burrs, seeds, straw, and sand in wool may be cited. Whatever the impurity be, it is usually necessary to remove it with the least possible damage to the fibre and to leave the fibre in a condition for being spun into a good useful yarn as already defined.

The processes preparatory to spinning are very varied, naturally being adapted to each particular fibre. The principles involved, however, are all comprised in the following

machines,[1] the action of which will be described after the natural requirements of the various fibres have been considered.

MACHINE.	MATERIALS FOR WHICH EMPLOYED.
The Gin	For cotton.
The Washing or Scouring Machine . . .	Wools and hairs.
The Dryer . . .	Wools, hairs, etc.
The Scutcher . . .	(a) For cotton. (b) For flax.
The Backwasher . .	Worsted slivers and tops.
The Gill-box . . .	Long wools and silk (modified form).
The Carder . . .	Medium and short wools and cotton.
The Dresser . . .	Waste silk and China-grass.
The Comb . . .	Wool, cotton, and sometimes silk and China-grass.
The Drawing-box . .	Wool, cotton, and silk.
The Cone Drawing-box .	Wool and cotton.
The French Gill or Drawing-box	Short wools.

The important points to study about these machines are, firstly, the principle underlying their construction; secondly, the way the material should be prepared for presentation to these machines; and, thirdly, the way in which these machines should deliver the material ready for the ensuing process or processes. Before dealing with these points, however, the natural requirements of each fibre should be considered, as it must always be the fibre which decides the type of preparing machine—even iron

[1] Net Silk Machining is treated separately in Chapter XV.

possibly alkali, so that perfect control of the temperature, heat, and strength of the liquor is obtained.

The yolk, sand, dirt, etc., got out of the wool must be disposed of. Thus, satisfactory means of emptying the bowls must be adopted, drain pipes being suitably fixed to the bowl or bowls to deliver the liquor to the settling or waste product tanks.

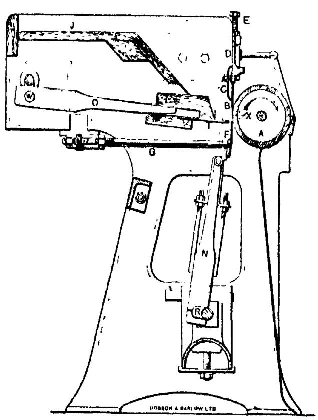


FIG. 23A. Section of Single Macarthy Cotton Gin.

But, again, during the operation of scouring the dirt and grease, etc., should be got away from the wool entering the bowl, this being usually effected by the settling which takes place by floating the liquor out with the wool and arranging for a tank at the side for the grease, sand, dirt, etc., to settle into, but so constructed that it may be readily cleaned out.

The propelling of the wool from one end of the tank to the other and especially taking it out of the machine

are also matters which require very careful thought and arrangement.

Scouring sets now frequently consist of four or five machines giving about 60 to 80 feet of bowl, in which the wool is immersed on an average for about eight minutes.

It may be interesting here to give a brief *résumé* of the evolution through which wool scouring has passed.

The first idea was to pass the wool rapidly through the scouring liquor; this matted the wool, prevented perfect scouring, and resulted in bad work throughout all subsequent processes.

Then the idea of forcing the scouring liquor through the wool was tried, with a very similar result.

Then it was realized that the natural tendency of wool to open out when placed in water—when the surface tension was removed—must be made the basis of wool scouring, and the wool was floated along with the scouring liquor.

Then the idea of a wet nip or "possers" was tried and found wanting, a wet nip apparently nipping dirt into the wool.

Finally it was realized that a combination of circumstances and conditions was necessary, that attention must be paid to all points, and the bearing of one point upon another fully taken account of. Thus were evolved the sets of modern wool-scouring machines in which the necessary agitation may be obtained, but which deliver the wool free, clean and wonderfully dry.

Modifications of wool-scouring machines to effect "wool steeping," and thereby reclaim the valuable potash salts, are also placed upon the market.

The Dryer.—There are several forms of drying machine,

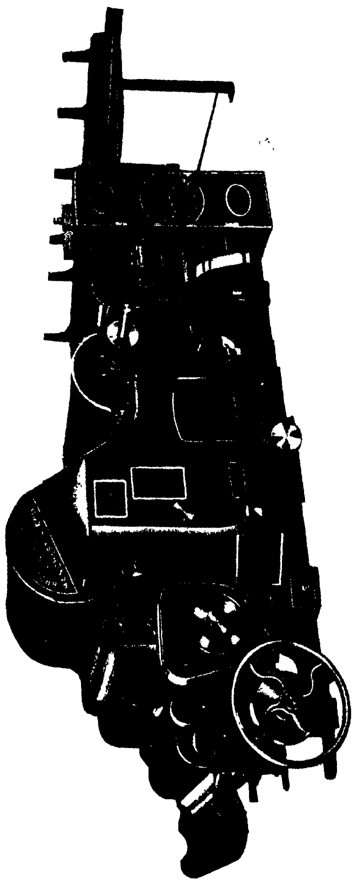


FIG. 24.—The Cotton Scutcher.

such being necessary in the case of English and cross-bred wools after scouring and also useful in such operations as carbonizing. The drying machine has followed an evolution similar to the scouring machine. The material to be dried has been held and air forced through it—as in the case of the table dryer; the material to be dried has been carried into the drying air, and last, and perhaps best of all, the mean between the two has been adopted as in the latest form of McNaught dryer.

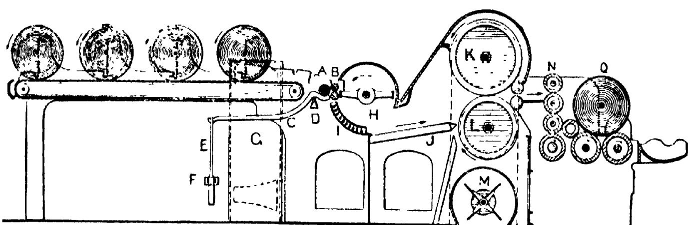


Fig. 24A.—Section of Single Cotton Scutcher.

The Cotton Scutcher.—This is a machine to thoroughly disintegrate and clean the cotton prior to carding. Briefly it consists of "cage" rollers upon which the cotton is blown, which pass it forward until eventually it is delivered as a lap. Suitably arranged "grids" allow sand and heavy foreign matters to drop out of the air currents; thus the cotton is fairly well cleaned and freed prior to carding (Figs. 24 and 24A).

The Flax Scutcher.—This is a machine to beat and break the flax straw after retting so that it is in a suitable state for the dressing frame. It is practically a "breaker" of the flax straw and also a partial cleanser (Fig. 25).

The Backwasher.—This machine usually consists of two small washing or scouring tanks, drying cylinders, and

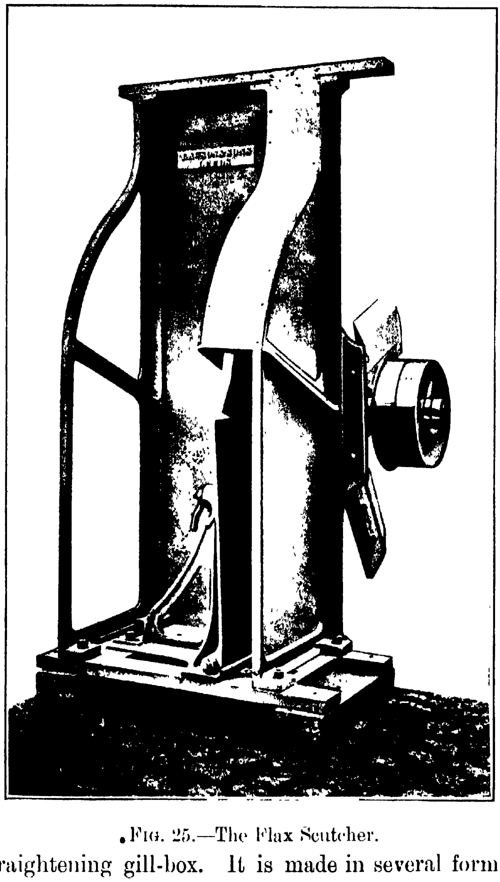


FIG. 25.—The Flax Scutcher.

a straightening gill-box. It is made in several forms, for each type certain constructional advantages or advantages

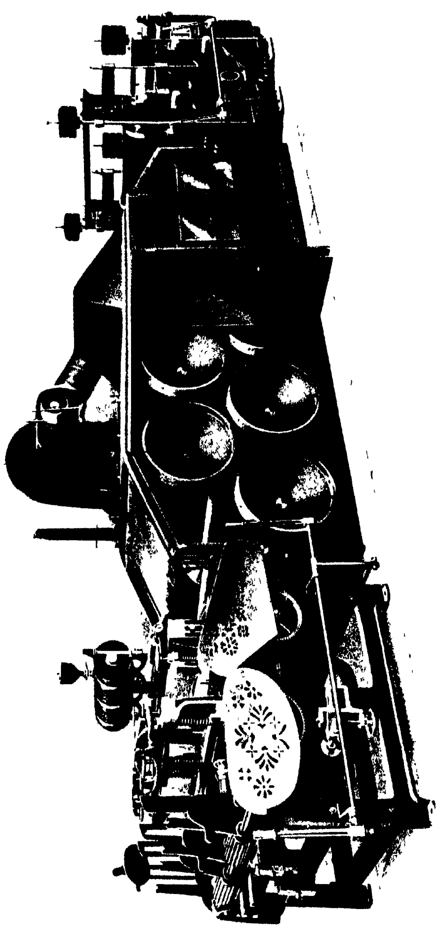


Fig. 26.—The Backwasher with Hot-air Drying.

for the material treated being claimed. It is employed either before (in England) or after (in France) combing to thoroughly clean worsted slivers or "tops," for not only does the wool become sullied in passing through the several preparing machines, but impurities which cannot be extracted in the scouring bowls have revealed themselves and may here be conveniently got rid of. The process of "blueing" to give a white appearance to the slivers or tops is frequently resorted to, and is usually effected on the backwasher. The latest innovation in this machine is the adoption of hot air drying in place of cylinder drying (see Fig. 26).

The Preparing Gill-box.—This consists of a pair of back rollers, gills or fallers riding on screws, and front rollers, with feed sheet and lap, balling-head or can delivery. The action on the wool may be either a combing action or principally a drawing action. For example, when wool is much matted the fallers, working quicker than the back rollers, comb out the fibres and deliver them to the front rollers, which should be set to the fallers. But when the material has been much worked and is fairly straight, the faller-pins simply slip through the fibres and consequently can only act as supports between back and front rollers; in other words, the operation becomes largely a drawing operation.

As pointed out with reference to cotton, the distance apart of drawing rollers, size of rollers, etc., must be very carefully considered. With wool the ratch or distance between back rollers and fallers or back rollers and front rollers is equally important, but as the wool fibre is so much larger than the cotton fibre the size of the rollers need only be

taken into account from a wear and tear and possibly from the grip and weighting points of view.

The Preparing Gill-box may be best considered as an

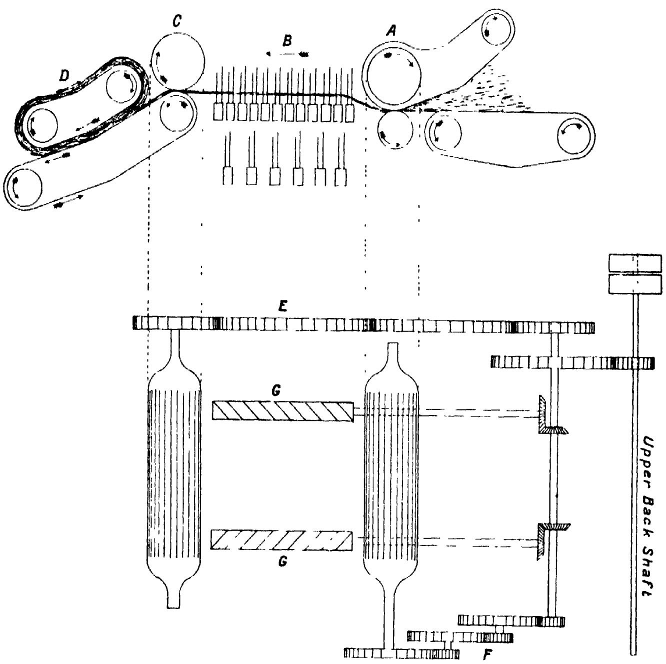


FIG. 27.—Plan and Elevation of Sheeter Gill-box. *A*, back rollers; *B*, fallers set with pins (gills); *C*, front rollers; *D*, sheeting leathers; *E*, train of wheels driving front rollers; *F*, train of wheels driving back rollers; *G*, screws driving the fallers or gills.

admirable straightener for wool and the various long animal fibres, and also as a mixer for fibres of varying qualities or colours (see Figs. 27 and 27A).

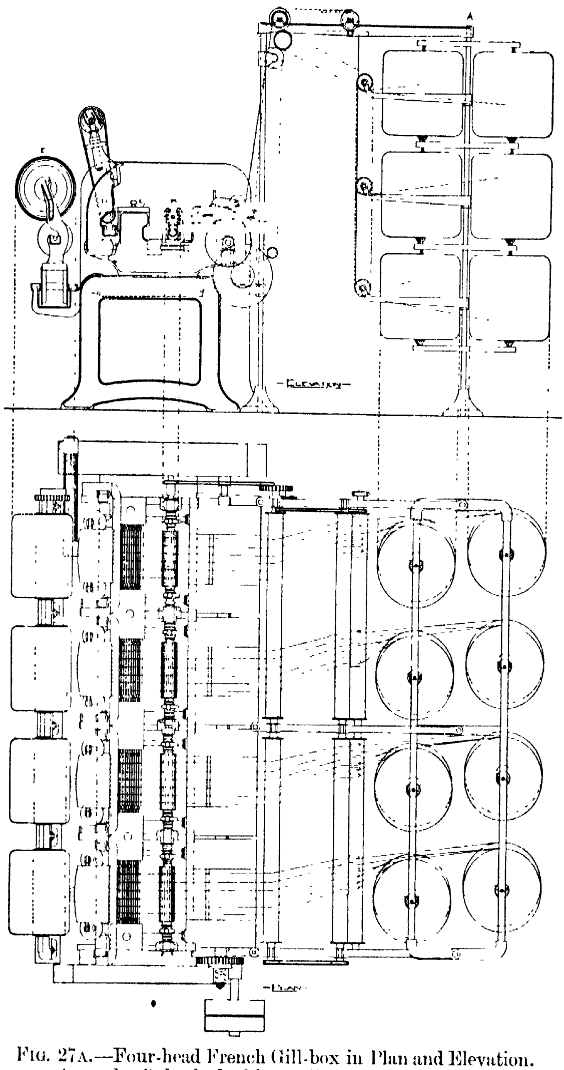


FIG. 27A.—Four-head French Gill-box in Plan and Elevation. *A*, creel; *B*, back drafting rollers; *C*, pinned fallers or gills; *D*, front drafting rollers; *E*, balling head.

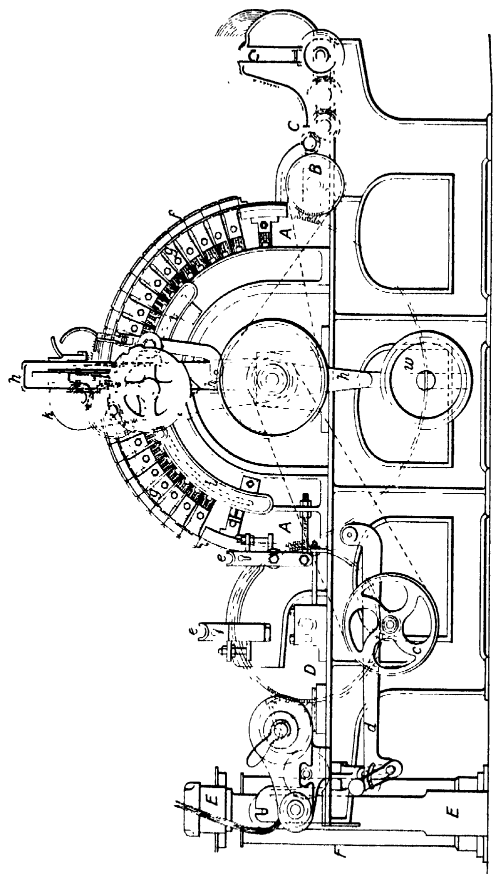


Fig. 28.—Self-cleaning Flat Cotton Carder, illustrating the Evolution from the Early Form of Card to the Revolving Flat Card.

The Carder.—This machine has been evolved from the hand-cards, such as are still used in the home industries of Scotland and Ireland. The first step towards an auto-

matic card was made when a cylinder—which might be turned by hand—was clothed with card-clothing and the wool worked between this cylinder and a flat card held in the hand. This early form of card gave rise to the flat and the revolving flat cards still largely employed in the cotton trade. Finally the whole of the carding was effected by cards mounted upon cylinders, and after many trials, involving both successes and failures, the modern roller card was evolved. It is here interesting to note that, owing to the susceptibility of cotton to air blasts, the cotton roller card is invariably made narrow and enclosed more than is the wool card; while, as a matter of fact, probably due to this, and also to the fibre length, the flat card seems the favourite for cotton (see Fig. 28).

In working carding machinery there are two main points to be attended to, viz., the satisfactory carding of the material and the designing and arrangements of the various parts to work to the greatest advantage with the least possible wear and tear. The satisfactory carding of the material depends in the first place upon the principle upon which the card works. This in the case of the roller card is as follows:—The swift acts as the main carrying cylinder constantly endeavouring to pass the wool forward, but is opposed by the teeth of the workers, which, acting as a sort of sieve, do not allow material to pass them until it is finely divided up. Thus from beginning to end of a card the workers should be set closer and closer—the first worker a fair way off, the last close to the wires of the swift, but never touching.[1] Thus material is really worked

[1] This is not quite true, as in carding mungo, etc., the wires are set to run into one another.

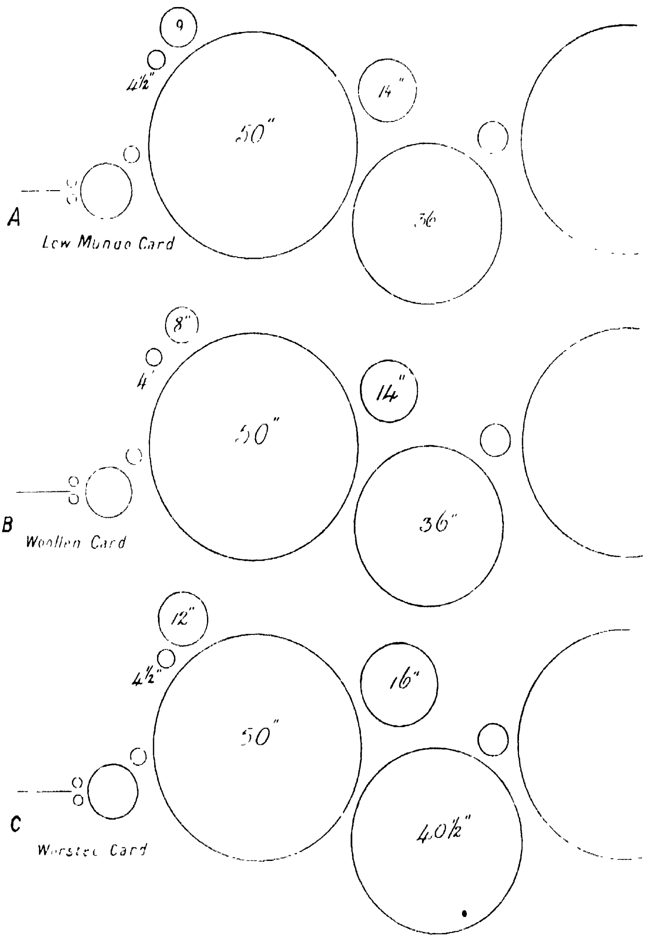


FIG. 29.—Illustrating the Sizes of Cylinders in Cards for Carding Various Qualities of Wool.

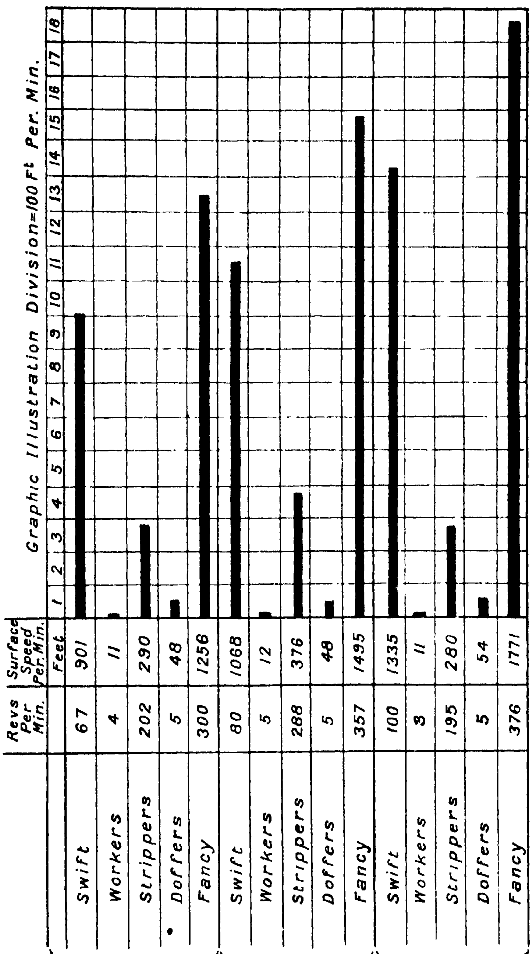


FIG. 30.—Graphic Illustration of the Surface of Speed of the Main Cylinders in *A*, low mungo card; *B*, woollen card; and *C*, worsted card.

		Count	Crown	Teeth Per Sq Inch
A	Swift	100	10	400
	Workers	105	10	420
	Strippers	90	9	324
	Doffers	110	10	440
	Fancy	65	7	182
B	Swift	130	11	572
	Workers	135	11	594
	Strippers	100	9	360
	Doffers	140	12	672
	Fancy	80	8	256
C	Swift	140	12	672
	Workers	145	12	696
	Strippers	110	9	396
	Doffers	150	13	780
	Fancy	80	8	256

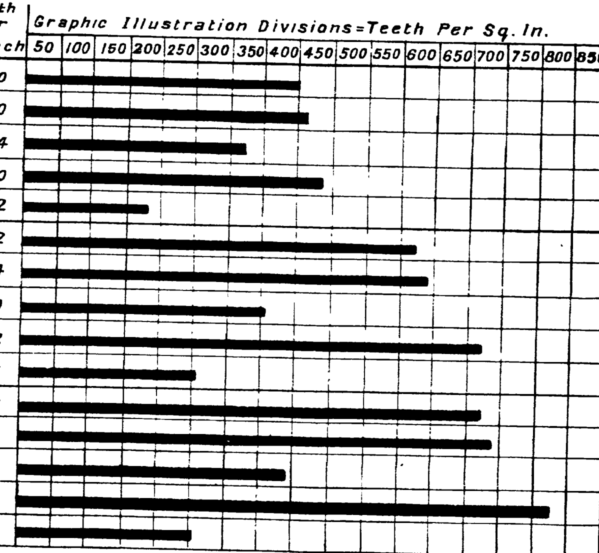


FIG. 31.—Graphic Illustration of the Wire Clothing of the Main Cylinders in *A*, low mungo card; *B*, woollen card; and *C*, worsted card.

by material. The material is condensed or "doubled" on the workers and then elongated or drafted by the strippers, and again by the swift stripping from the strippers. This is the carding operation; feed-rollers, licker-in, fancy and doffer being the means of conducting wool into and out of the machine. It will be noticed that the satisfactory accomplishment of the operation just described depends upon (a) the surface speeds of the rollers, which in part necessarily influence the size of these rollers; (b) the direction in which the rollers revolve; (c) the inclination or bend of the card teeth; and (d) upon the relative density of the card-teeth with which the various rollers are clothed. The wear and tear upon a card depend largely upon the size of the rollers, and of course upon the practical setting.

The material of which the cards are built is of course another important matter, but ordinary engineering principles here apply. Iron is more stable than wood but is readily broken, while wood is more convenient but does not long remain "true." The following diagrams and lists will illustrate the principles of carding and of satisfactorily clothing the card cylinders (see Figs. 29, 30, and 31).

The Dresser.—This machine takes the place of the comb when the material is (a) too rough, as in the case of flax, to be satisfactorily combed; or (b) too slippery, as in the case of silk and china-grass, to be satisfactorily combed.

Briefly, it consists of a series of boards, books or holders between which one end of the material to be dressed is firmly clamped and held; a framework upon which these boards may be fixed so as to be carried continuously into the machine or placed in the machine and withdrawn when necessary; and a series of cleansing combs with

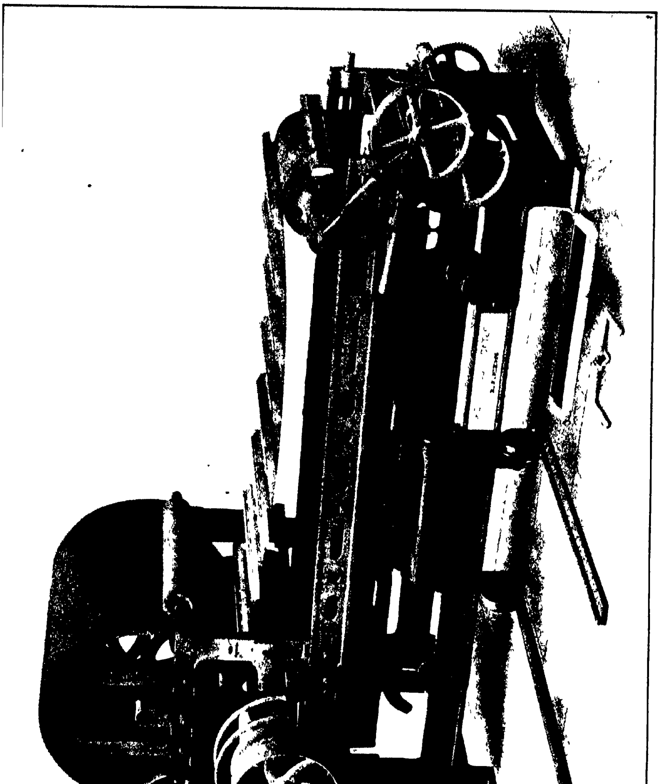


Fig. 32.—Silk Dressing Frame.

cleaning or noil arrangements so that they may work to the greatest advantage.

The material may be presented upwards to the combs as in the case of silk, or downwards as in the case of flax. In the case of silk-dressing the operation is undertaken more with the idea of averaging the fibres into the several different "drafts"; in the case of flax the operation partakes more of a cleansing character (see Fig. 32).

The Comb.—While combing may in part be said to be based upon the idea of averaging up the fibres, still more

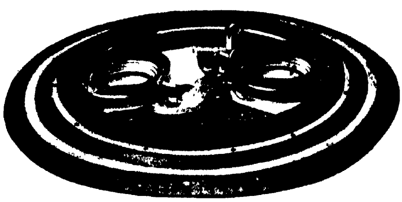


FIG. 33.—Position of Large and Two Small Circles in the Noble Comb.

truly may it be said to consist in combing out all fibres under a certain length, leaving the long or top wool to form what is termed the "top" and the short to form "noil." Along with combing, as with dressing, must go a straightening operation; in fact, in the days of the hand comb, the second combing was termed "straightening."

There are two types of comb in use, the horizontal circular and the vertical circular. The Noble comb is the best representation of the horizontal circular (Figs. 33 and 33A). The combing operation here is based upon the drawing out of the long fibres between the diverging circles until the one having the shortest end as it were leaves go, leaving the

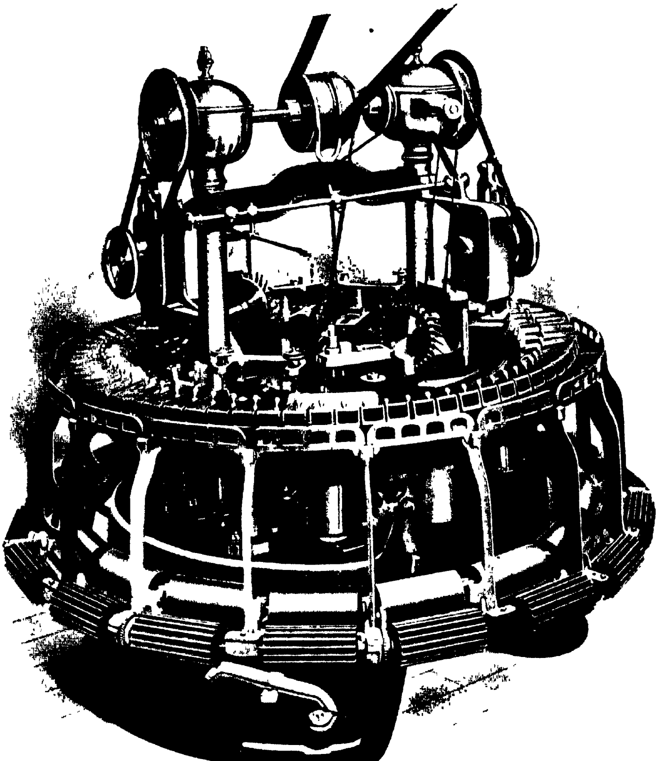


FIG. 33A.—Self-supporting Noble Comb, latest Form.

long fibres hanging on the outside of the small circle and the inside of the large circle, from which they are drawn off by suitably placed rollers. The noil in the meantime

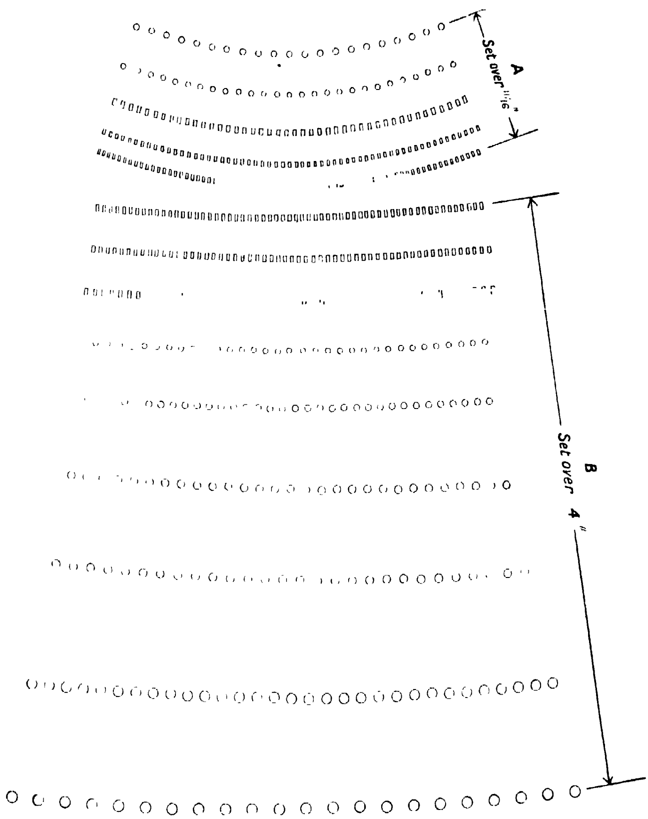


FIG. 34.—Pricking from a Long Wool Noble Comb Circle. *Note.*—For a Botany Comb the "set over" for *A* is $\frac{5}{8}''$, the "set over" for *B* is $1\frac{3}{4}''$.

has been held within the pins, and ultimately is taken off from between the pins of the small circles by what are known as noil knives. The pinning of Noble comb circles

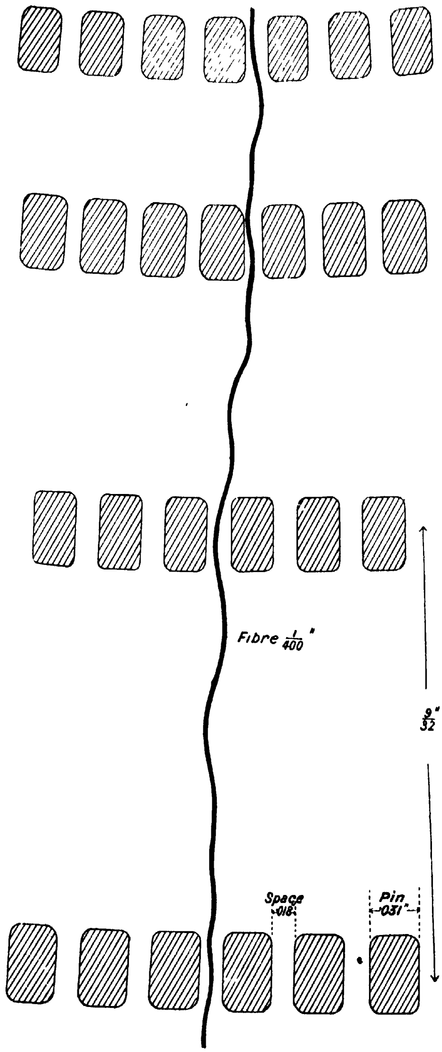


FIG. 34A.—View of Wool Fibre in the Pins of a Noble Comb. Drawn to scale.

should be definitely based upon the diameter of the pin and the space to leave in between for the fairly free running of the fibres—say, one-fourth pin to three-fourths space.

As the satisfactory holding of the fibres by the pins is the basis of the Noble comb, it will be realized that, not only must the distance apart and thickness of the pins be taken into account, but also the set-over or space over which the pins are set (see Figs. 34 and 34A).

The Heilman comb in its various forms is the best example of the vertical circular comb. Briefly, it consists of a pair of jaws to hold a tuft of fibres, a comb cylinder to comb one end of this tuft, a pair of rollers to take hold of the combed end, combs through which the uncombed end may be drawn and thus combed, and a continuous lap forming arrangement. As in most combs the operation of combing must be more or less gradual, the comb cylinder here employed has the first row of teeth fairly openly set, the next closer, and so on, the finest being set about 60 per inch for wool and about 80 for cotton. There is also a preparation of the sliver for combing prior to the jaws referred to coming into action.

The Drawing-box.—This is similar in many respects to the gill-box, but lacks the gills or fallers, their place being taken by carriers which support the wool between back and front rollers. The distance between back and front rollers is usually somewhat greater than the length of the longest fibre being treated, so that in part fibre may be said to be worked by fibre (see Fig. 35).

The Cone Drawing-box.—So far as the drawing action of this box is concerned the action is the same as in the ordinary box. As remarked, however, with reference to

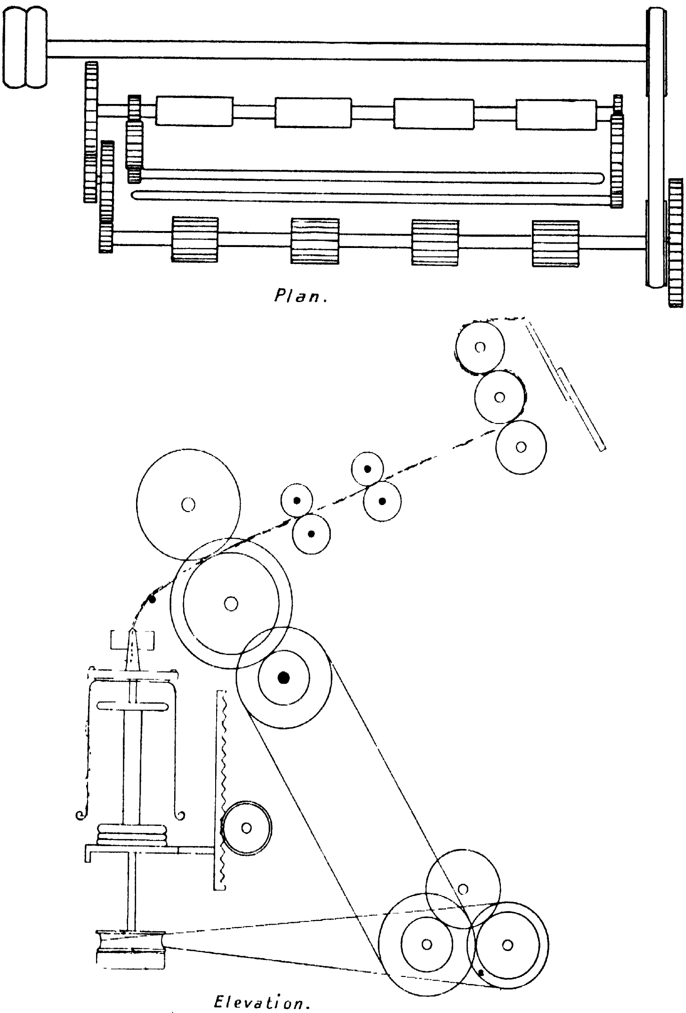


FIG. 35.—Plan and Elevation of a Drawing-box.

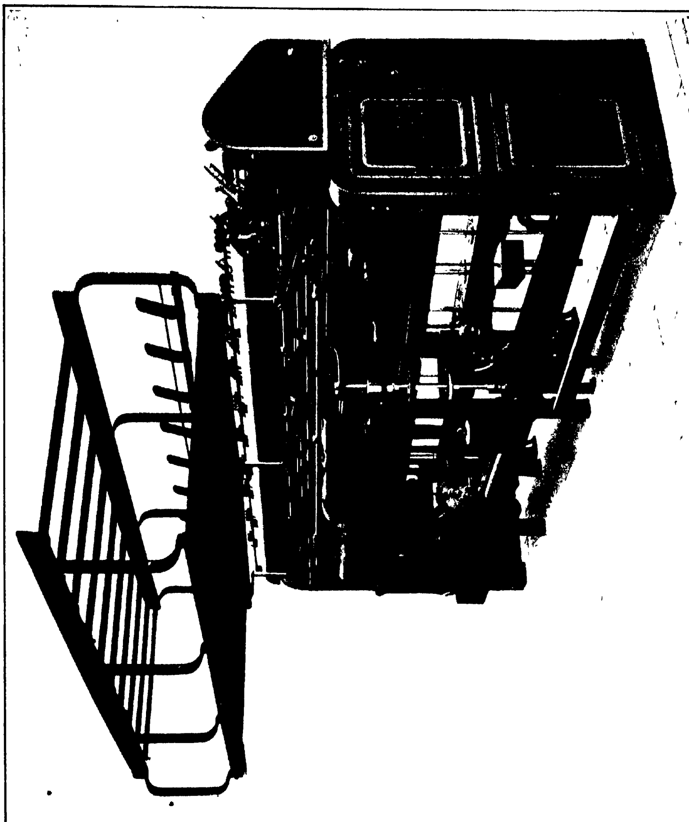


Fig. 36.—Cone Drawing-box.

the scouring machine, the getting of the material into the machine and out of the machine again may be no trifling matter; in fact it may be and in this case is more of a problem than the main operation itself. To put the matter

briefly—in a cone-box the material is positively wound on to suitable sized bobbins with practically no strain upon it, while in the case of the ordinary drawing-box twist must

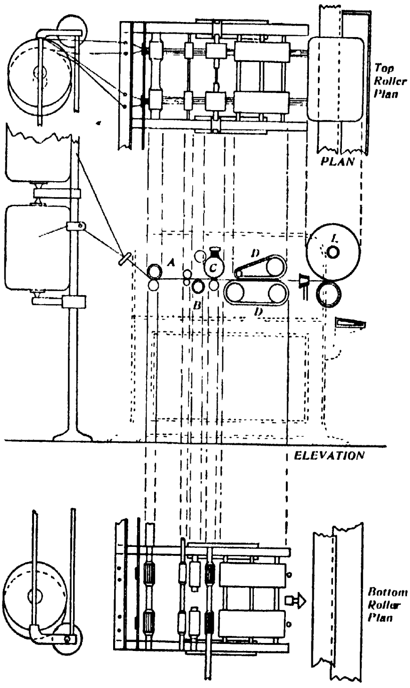


FIG. 37.—French Drawing Frame in Plan and Elevation.—*A*, back drafting rollers; *B*, porcupine; *C*, front drafting rollers; *D*, rubbing leathers; *E*, balling head.

be put into the sliver to give it sufficient strength to pull the bobbin round. It is thus evident that with a cone-regulated wind-on two great advantages accrue—firstly, the

slivers may be drawn much softer and thus a better final spin obtained, and less consumption of power in the machine be required; and secondly, larger bobbins may be employed, resulting in more economical working, especially for large quantities. It is also interesting to note that as both flyer and bobbin are positively driven, bobbin may lead flyer instead of flyer leading the bobbin as ordinarily obtains. The relative advantages of these two methods are worthy of careful consideration.

It is interesting to note that with the cone frame the

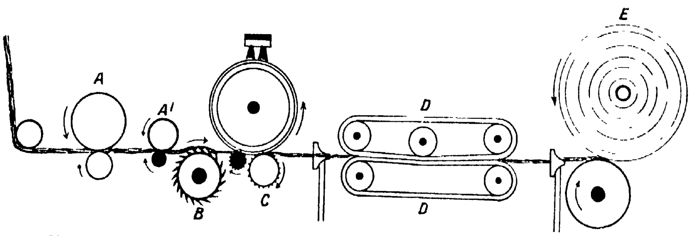


FIG. 37A.—Enlarged View of principal parts in a French Drawing-box.

limit of the strength of the sliver is not in the winding on to the bobbin, but in the pulling of the sliver or roving off the bobbin (see Fig. 36).

The French Drawing-box.—This consists of back-rollers (*A*), porcupine or circular gill or fibre controller (*B*), front rollers (*C*), rubbing leathers (*D*), and delivering head (*E*) (Figs. 37 and 37A). No twist is here inserted, so that a pith-like thread is produced. The arrangement enables doubling and drafting to be effected most readily, and practically does away with the necessity for gills working on screws. The value of this method of producing soft spin mixtures has probably not yet been fully realized in this country.

CHAPTER VII

THE PRINCIPLES OF WEAVING

As previously remarked, the art of weaving, or perhaps more correctly the art of "interlacing," preceded that of spinning. The "wattles" we read of in connection with early methods of building were no doubt willow or other pliant stems of trees or plants interlaced to form a firm foundation for plastering upon. Baskets were similarly made from twigs of suitable thickness, and many other interlacings no doubt preceded the actual art of weaving in the evolution of every race and every country. The idea of actuating in two series all the strands running in one direction, forming a "warp," would soon develop where strands or threads of any required length were forthcoming to form the warp from. The half-heald worked by hand would then appear, followed by the full-heald bringing the feet into play as an aid to the hands. The method of throwing the weft through successive sheds or openings of the warp-threads would similarly pass through many stages before arriving at the present day shuttle and picking apparatus; indeed the fly shuttle itself only appeared in 1738. At first the whole length of warp would be stretched out upon the ground and the weaver would advance as he interlaced the weft from one end of the piece to the other. The idea of beaming the warp on to a roller and of winding up the

cloth as woven in order that the weaver might remain seated in one position and thus work to the greatest advantage is still in embryo in some semi-civilised districts. It is more than probable that long before the hand-loom was in any sense developed very elaborate textures were produced—very laboriously it is true—by hand, almost thread by thread and pick by pick. The art of gauze weaving, for example, was perfectly known to the Egyptians, as in mummy cloths we find some really elaborate styles of this order of interlacing. Pile weaving would also be practised in very narrow fabrics or ribbons. Thus it may be said that the art of weaving passed from the stage when very simple means were employed to effect interlacing, to the stage when very complex hand processes were employed in producing elaborate design; then through a stage in which endeavours were made to markedly increase the output by the hand method, finally culminating in the automatic production of fabrics on the power-loom. It may safely be said that so far as we can tell all the most intricate and pleasing methods of weaving by hand came to England from the Continent of Europe. On the other hand most of the mechanical methods of reproducing the somewhat complicated hand methods went from this country to the Continent. Of course there are exceptions to this, but such are exceedingly few and really trivial.

To-day it may be said that there are practically three kinds of weaving, viz.:—**Unit Weaving**, as illustrated in Axminster carpets; **Group Unit Weaving**, as illustrated in the ordinary loom; and **Average Weaving**, as illustrated in Lappet weaving and in the Electric Jacquard.

The Axminster carpet method of weaving is simply an

imitation of the Oriental knot, as practised in the making of Turkey carpets and in certain Gobelins tapestries, both hand productions. The weaver—if such he may be termed—simply selects from his bundle of yarn the right colour for a small defined section of the carpet he is making, and knots this yarn into that section. As there is no limit to the colours employed and as the structure is firm and well knotted together, the result obtained is usually magnificent. The Axminster carpet loom follows this hand method as exactly as possible. As each individual thread (or perhaps pair of threads) is "latched" by another distinct thread, hence the term "unit" weaving.

The group-unit system results from arranging as many threads as possible in a warp to interlace in the same way, and then to fix these upon the same apparatus—usually a heald-shaft—which thus very simply works them all together exactly as required. Thus if there are 2,000 ends in a warp and plain cloth is to be produced, the odd ends to the number of 1,000 will be mounted on one heald-shaft, and the even ends to the number of 1,000 upon another heald-shaft. Thus each thread is a unit to itself, but there is a grouping of units to effect simplification in production. This system is by far the most frequently employed, and consequently will be dealt with at some length later.

The average weaving method is quite distinct from the other two methods, as no attempt is here made to work each thread with absolute accuracy as in the other two methods. In certain Electric Jacquards,[1] for example, a rough selection of the threads in accordance with the

[1] Carver's Electric Jacquard, at present being tried in the linen districts of Ireland, is an excellent example of this system.

requirements of the design is effected, while in the case of the Lappet frame, although an endeavour is made to work so accurately that each needle places its thread precisely in the cloth, still a rough averaging up only is attained. With more perfect mechanical appliances it is just possible that this system will be much more fully utilised in the future. The Szczepanik designing and card-cutting apparatus forms an interesting attempt in this direction.

Group-Unit Weaving.—In this method of weaving it is obviously necessary that all previous processes to the actual weaving should be perfectly carried out if really satisfactory weaving is to be the result. The first necessity is a yarn which will weave satisfactorily. To obtain this at a reasonable rate becomes year by year more difficult, as the tendency towards cheapness becomes more pronounced. As a rule a yarn with a minimum strength of 4 ounces is the very weakest which should be employed.

The warping operation consists in obtaining a given number of threads (say 2,000), of a given length (say 100 yards), in a given order (sometimes any order will do; sometimes a colour scheme, say four black, two grey, four white, two grey, must be maintained), and at an equal tension, in a convenient form for being wound on to the warp-beam of the loom. Hand-warping is only resorted to for pattern warps. The upright warping mill is still largely employed both for cotton and wool warps, but is frequently inefficient, as it tends to develop stripiness in the pieces—both a sectional stripiness and a distributed stripiness, owing to its failure to control the tension on individual threads unless very carefully set and geared.

The cheese system is still largely employed, but again tends to show a defect in cheese widths, which while not noticeable in fancies, in plains may become very objectionable. The Scotch or horizontal warping mill is gaining in favour and for fancies is practically perfect, but for plains also tends to show a defect in section of the number of bobbins warped with. The warper's beam system, all things considered, seems the most perfect system, as all defects tend to become distributed and thus neutralise one another. This system is simplicity itself for plain warps, and for fancies, with a little arrangement, may also be used to advantage.

Sizing follows warping, the idea being to coat the thread and thus prevent its wearing fluffy in the gears of the loom; and further, if possible, to strengthen the thread. In the past the tendency has always been to put vegetable size on to vegetable fibres and animal size on to animal fibres. To-day, however, the tendency is to put vegetable sizes on to every kind of material, no doubt on account of cheapness. Of course care must be taken that the vegetable size is readily extracted from the fabrics during the finishing operation, otherwise clouded pieces, owing to this irregular sizing, may result. Certain combination warping and sizing machines are placed on the market, but the call for these has rather declined than increased.

After sizing follows dressing, which consists in winding the warp at a uniform tension—both across and lengthwise—on to the loom beam. English dressers prefer to compress the warp on the beam with the tension that the warp itself will naturally stand, but American dressers often attempt to compress the warp still further in order that the

warp beam may be made to carry a greater length of warp, thus saving a certain number of tyings-in.

Drawing or twisting-in follows. If the warp is to be passed through a new set of gears it will have to be drawn by hand through these. A good drawer-in working with a reacher-in passes about 1,000 to 1,200 threads per hour. Should it only be necessary to twist or tye the new warp to the warp—or "thrum" as it is called -already in the gears this may readily be effected either in the loom or out of the loom at the rate of about 1,800 threads per hour. If the warp is plain and no precise order of coloured threads necessary, the recently introduced "Barber-Warp Tyer" will twist or rather tye-in a warp out of the loom at the rate of 250 knots or threads per minute.[1] This machine works on the "average" principle; thus, although almost perfect, it cannot be relied upon to maintain an absolute order of the colours in a fancy warp.

Reference may here be made to the various styles of healds put on the market. It is probable that not nearly sufficient attention is given to this section of the work, as good wearing, easily regulated, and convenient styles of healds are most necessary. Of late wire healds seem to have come much more into use, but there are good and very bad styles of wire healds, so that great care should be exercised in selecting these. Again, a shed full of wire healds means much more weight for the engine to lift.

After drawing-in, "sleying," or the passing of the threads singly or in groups of two, three, four, five or six through the reed is necessary. This is effected at the rate of about

[1] A mechanical "drawing-in" machine is now placed on the market.

2,000 threads per hour by means of two sleying knives worked alternately by hand. Reeds again should receive more attention than they at present claim. English reed makers can make a good ordinary article, but German and French reed makers are much ahead in the production of really fine reeds with properly feathered dents regularly soldered together.

After the warp has been passed through the gears and reed the warp-beam and gears must be lifted into the loom—the gates in the loom shed being sufficiently wide to ensure this without damage to either warp or gears, the gears hung in position, the reed placed in position, the warp attached to the cloth beam by means of a level wrapper, and then after the necessary gearing up the actual operation of weaving ensues.

The principal movements during weaving are as follows:

Shedding, or forming a passage for the shuttle through the warp threads, certain of the threads being definitely raised and the others depressed; threads lifted and depressed being varied for a succession of sheds.

Picking, or the throwing of the shuttle through the shed which has been formed, leaving the pick behind it in the shed.

Beating-up, *i.e.*, the reed beating the pick just inserted up to the cloth already formed to make a firm, even texture.

Letting-off, *i.e.*, unwrapping warp from the warp-beam to take the place of that used up in interlacing with the weft to form the cloth.

Taking-up, *i.e.*, winding up on to the cloth beam the cloth woven, this movement of necessity being worked in conjunction with the letting-off.

There are two types of comb in use, the horizontal circular and the vertical circular. The Noble comb is the best

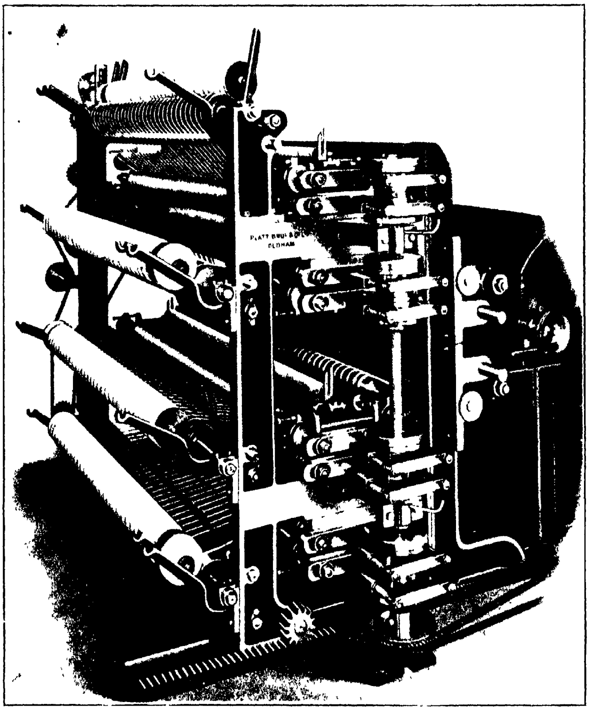


FIG. 39.—Leather Tape Condenser.

representation of the horizontal circular (Figs. 38 and 38A). The combing operation here is based upon the drawing out of the long fibres between the diverging circles until the one having the shortest end as it were leaves go, leaving the

long fibres hanging on the outside of the small circle and the inside of the large circle, from which they are drawn off by suitably placed rollers. Small drawing-off rollers enable this comb to satisfactorily treat very short wools. The noil in the meantime has been held within the pins, and ultimately is taken off from between the pins of the small circles by what are known as noil knives. The pinning of Noble comb circles

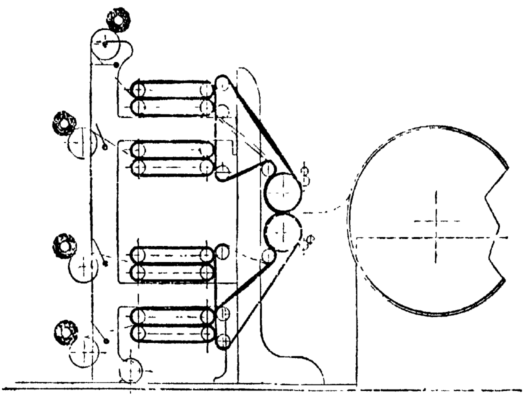


FIG. 39A.—Leather Tape Condenser.

should be definitely based upon the diameter of the pin and the space to leave in between for the fairly free running of the fibres—say, one-fourth pin to three-fourths space.

As the satisfactory holding of the fibres by the pins is the basis of the Noble comb, it will be realized that, not only must the distance apart and thickness of the pins be taken into account, but also the set-over or space over which the pins are set (see Figs. 40 and 40A).

The Heilman comb in its various forms is the best

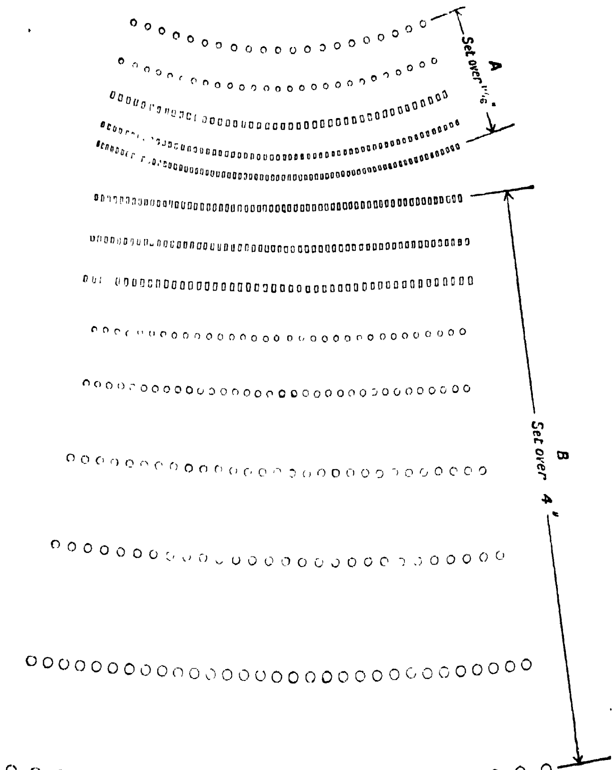


FIG. 40.—Pricking from a Long Wool Noble Comb Circle. *Note.*—For a Botany Comb the "set over" for *A* is $\frac{5}{8}$", the "set over" for *B* is $1\frac{3}{4}$".

example of the vertical circular comb. Briefly, it consists of a pair of jaws to hold a tuft of fibres, a comb cylinder to comb one end of this tuft, a pair of rollers to take hold of

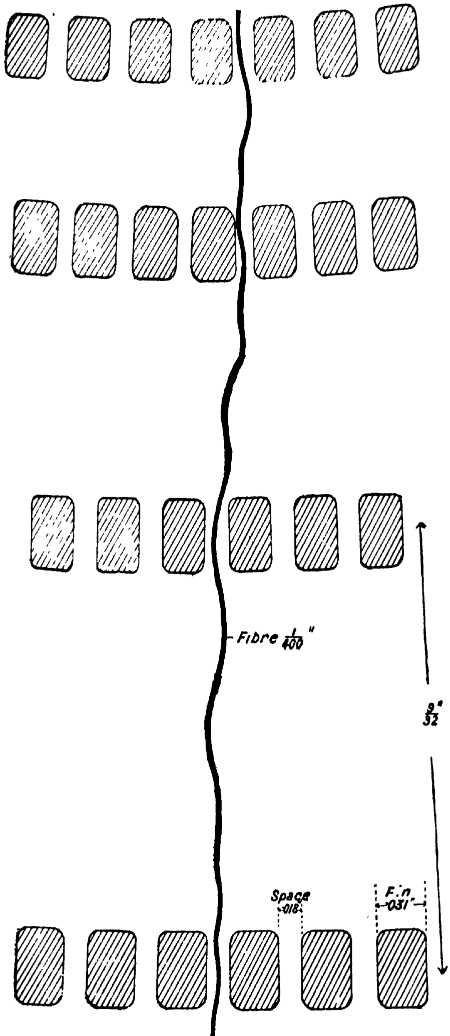


FIG. 40A.—View of Wool Fibre in the Pins of a Noble Comb. Drawn to scale.

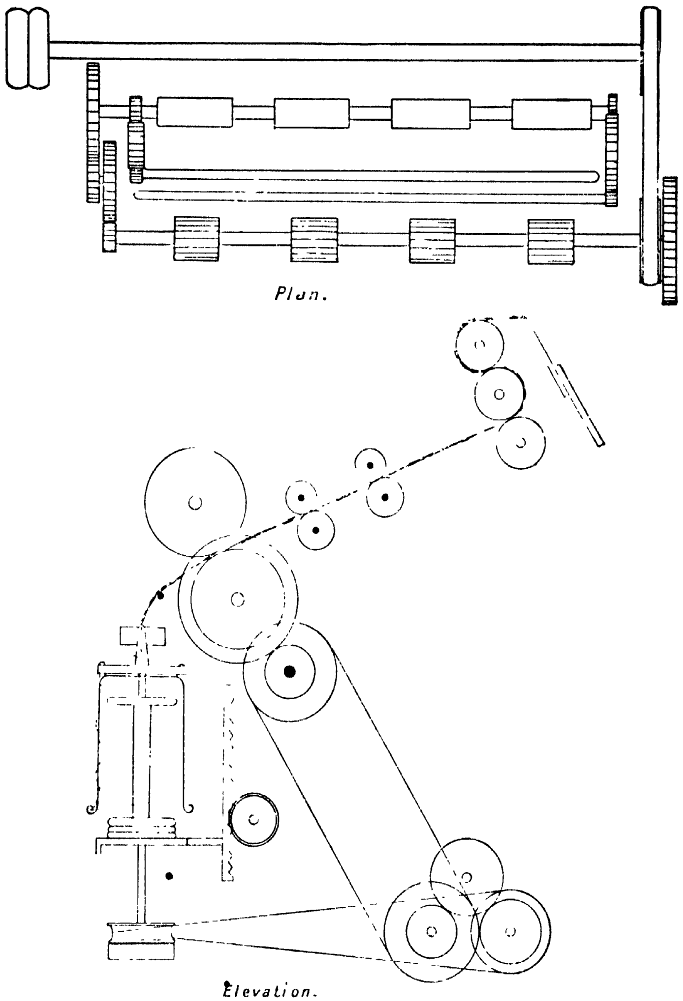


FIG. 41.— Plan and Elevation of a Drawing-box.

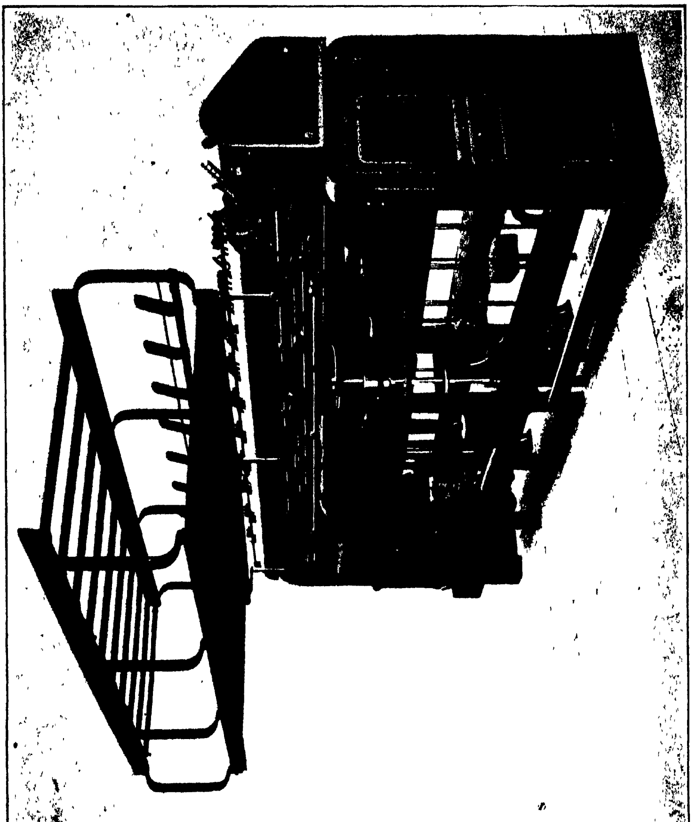


FIG. 42.—Cone Drawing-box.

the combed end, combs through which the uncombed end may be drawn and thus combed, and a continuous lap forming arrangement. As in most combs the operation of combing must be more or less gradual, the comb cylinder

here employed has the first row of teeth fairly openly set, the next closer, and so on, the finest being set about 60 per inch for wool and about 80 for cotton. There is also a

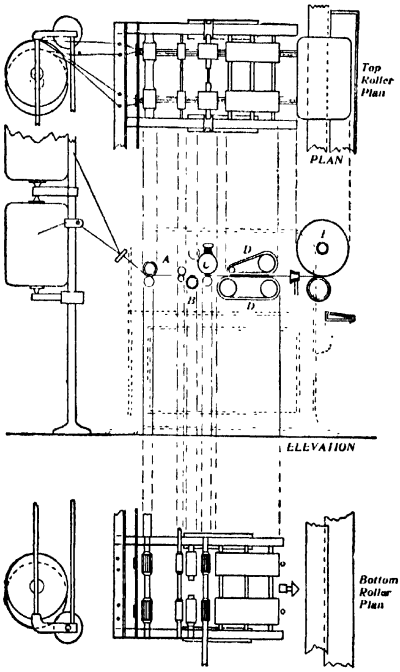


FIG. 43.—French Drawing Frame in Plan and Elevation.—*A*, back drafting rollers; *B*, porcupine; *C*, front drafting rollers; *D*, rubbing leathers; *E*, balling head.

preparation of the sliver for combing prior to the jaws referred to coming into action.

The Drawing-box.—This is similar in many respects to the gill-box, but lacks the gills or fallers, their

place being taken by carriers which support the wool between back and front rollers. The distance between back and front rollers is usually somewhat greater than the length of the longest fibre being treated, so that in part fibre may be said to be worked by fibre (see Fig. 41).

The Cone Drawing-box.—So far as the drawing action of this box is concerned the action is the same as in the ordinary box. As remarked, however, with reference to

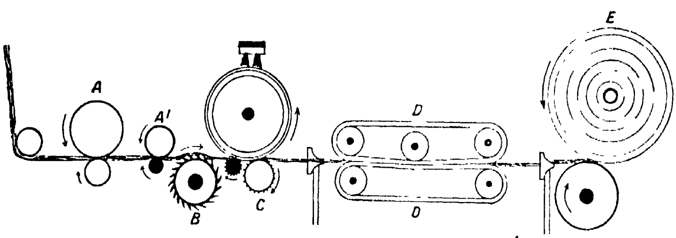


FIG. 43A. Enlarged View of principal parts in a French Drawing-box.

the scouring machine, the getting of the material into the machine and out of the machine again may be no trifling matter; in fact it may be and in this case is more of a problem than the main operation itself. To put the matter briefly—in a cone-box the material is positively wound on to suitable sized bobbins with practically no strain upon it, while in the case of the ordinary drawing-box twist must be put into the sliver to give it sufficient strength to pull the bobbin round after the flyer. It is thus evident that with a cone-regulated wind-on two great advantages accrue—firstly, the slivers may be drawn much softer and thus a better final spin obtained, and less consumption of power in the machine be required; and secondly, larger bobbins may be employed, resulting in more economical working, especially for large

quantities. It is also interesting to note that as both flyer and bobbin are positively driven, bobbin may lead flyer instead of flyer leading the bobbin as ordinarily obtains. The relative advantages of these two methods are worthy of careful consideration.

It is interesting to note that with the cone frame the limit of the strength of the sliver is not in the winding on to the bobbin, but in the pulling of the sliver or roving off the bobbin (see Fig. 42).

The French Drawing-box.—This consists of back-rollers (*A*, *A′*), porcupine or circular gill or fibre controller (*B*), front rollers (*C*), rubbing leathers (*D*), and delivering head (*E*) (Figs. 43 and 13A). No twist is here inserted, so that a pith-like thread is produced. The arrangement enables doubling and drafting to be effected most readily and with little fibre strain, and practically does away with the necessity for gills working on screws. The value of this method of producing soft spin mixtures has probably not yet been fully realized in this country. It is interesting to note that French drawing-boxes are interesting not only owing to their essential principle of the open treatment of wool slivers, but also owing to the special feed and delivery necessitated. Thus the feed-creel carries the balls of slivers upright, thus reducing friction; and the delicate slivers issuing from the rubbing leathers are built up on an ordinary traverse balling head or, if very fine and delicate, as in the last rover, upon a variable-traverse balling head, which lays the slivers side by side in a beautifully exact manner.

CHAPTER VII

THE PRINCIPLES OF WEAVING

As previously remarked, the art of weaving, or perhaps more correctly the art of "interlacing," preceded that of spinning. The "wattles" we read of in connection with early methods of building were no doubt willow or other pliant stems of trees or plants interlaced to form a firm foundation for plastering upon. Baskets were similarly made from twigs of suitable thickness, and many other interlacings no doubt preceded the actual art of weaving in the evolution of every race and every country. The idea of actuating in two series all the strands running in one direction, forming a "warp," would soon develop where strands or threads of any required length were forthcoming from which to form the warp. The half-heald worked by hand would then appear, followed by the full-heald bringing the feet into play as an aid to the hands. The method of throwing the weft through successive sheds or openings of the warp-threads would similarly pass through many stages before arriving at the present day shuttle and picking apparatus: indeed the fly shuttle itself only appeared in 1738. At first the whole length of warp would be stretched out upon the ground and the weaver would advance as he interlaced the weft from one end of the piece to the other. Then the idea of winding the woven cloth on to a roller, letting in the warp from an extension rope, would be developed. The idea of beaming the warp on to a

roller and of winding up the cloth as woven in order that the weaver might remain seated in one position and thus work to the greatest advantage is still in embryo in some semi-civilized districts. It is more than probable that long before the hand-loom was in any sense developed very elaborate textures were produced—very laboriously it is true—by hand, almost thread by thread and pick by pick. The art of gauze weaving, for example, was perfectly known to the Egyptians, as in mummy cloths we find some really elaborate styles of this order of interlacing. Pile weaving would also be practised in very narrow fabrics or ribbons. Thus it may be said that the art of weaving passed from the stage when very simple means were employed to effect interlacing, to the stage when very complex hand processes were employed in producing elaborate design; then through a stage in which endeavours were made to markedly increase the output by the hand method, finally culminating in the automatic production of fabrics on the power-loom. It may safely be said that so far as we can tell all the most intricate and pleasing methods of weaving by hand came to England from the Continent of Europe. On the other hand most of the mechanical methods of reproducing the somewhat complicated hand methods went from this country to the Continent. Of course there are exceptions to this, but such are exceedingly few and really trivial.

To-day it may be said that there are practically three kinds of weaving, viz.:—**Unit Weaving**, as illustrated in Axminster carpets; **Group Unit Weaving**, as illustrated in the ordinary loom; and **Average Weaving**, as illustrated in Lappet weaving and in the Electric Jacquard.

The Axminster carpet method of weaving is simply an

imitation of the Oriental knot, as practised in the making of Turkey carpets and in certain Gobelins tapestries, both hand productions. The weaver—if such he may be termed—simply selects from his bundle of yarn the right colour for a small defined section of the carpet he is making, and knots this yarn into that section. As there is no limit to the colours employed and as the structure is firm and well knotted together, the result obtained is usually magnificent. The Axminster carpet loom follows this hand method as exactly as possible. As each individual pile thread is "latched" by another distinct thread backed by other threads, the term "unit" weaving is employed.

The group-unit system results from arranging as many threads as possible in a warp to interlace in the same way, and then to fix these upon the same apparatus—usually a heald-shaft—which thus very simply works them all together exactly as required. Thus if there are 2,000 ends in a warp and plain cloth is to be produced, the odd ends to the number of 1,000 will be mounted on one heald-shaft, and the even ends to the number of 1,000 upon another heald-shaft. Thus each thread is a unit to itself, but there is a grouping of units to effect simplification in production. This system is by far the most frequently employed, and consequently will be dealt with at some length later.

The average weaving method is quite distinct from the other two methods, as no attempt is here made to work each thread with absolute accuracy as in the other two methods. In certain Electric Jacquards,[1] for example, a rough selection of the threads in accordance with the

[1] Carver's Electric Jacquard, employed to a limited extent in the linen districts of Ireland, is an excellent example of this system.

requirements of the design is effected, while in the case of the Lappet frame, although an endeavour is made to work so accurately that each needle places its thread precisely in the cloth, still a rough averaging up only is attained. With more perfect mechanical appliances it is just possible that this system will be much more fully utilised in the future. The Szczepanik designing and card-cutting apparatus forms an interesting attempt in this direction.

Group-Unit Weaving.—In this method of weaving it is obviously necessary that all previous processes to the actual weaving should be perfectly carried out if really satisfactory weaving is to be the result. The first necessity is a yarn which will weave satisfactorily. To obtain this at a reasonable rate becomes year by year more difficult, as the tendency towards cheapness becomes more pronounced. As a rule a yarn with a minimum strength of 4 ounces is the very weakest which should be employed.

The warping operation consists in obtaining a given number of threads (say 2,000), of a given length (say 100 yards), in a given order (sometimes any order will do; sometimes a colour scheme, say four black, two grey, four white, two grey, must be maintained), and at an equal tension, in a convenient form for being wound on to the warp-beam of the loom. Hand-warping is only resorted to for pattern warps. The upright warping mill is still largely employed both for cotton and wool warps, but is frequently inefficient, as it tends to develop stripiness in the pieces—both a sectional stripiness and a distributed stripiness, owing to its failure to control the tension on individual threads and groups of threads unless very carefully

set and geared. The cheese system is still largely employed, but again tends to show a defect in cheese widths, which while not noticeable in fancies, in plains may become very objectionable. The Scotch or horizontal warping mill is gaining in favour and for fancies is practically perfect, but for plains also tends to show a defect in sections of the number of bobbins

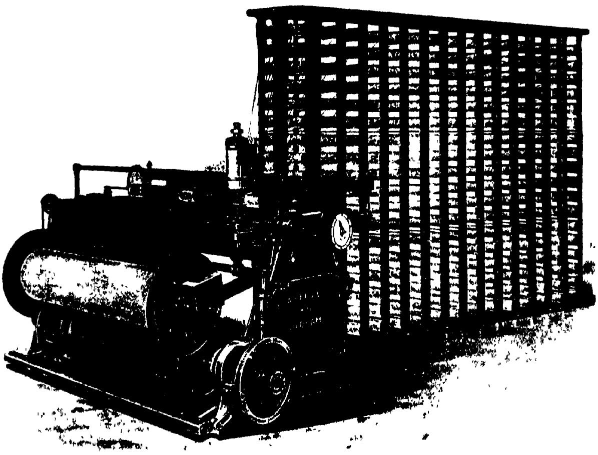


FIG. 44. Improved Beaming Machine.

warped with. The warper's beam system (Fig. 44), all things considered, seems the most perfect system, as all defects tend to become distributed and thus neutralize one another. This system is simplicity itself for plain wraps, and for fancies, with a little arrangement, may also be used to advantage. The American spooling system of warping appears to be losing favour, even in the United States and Canada, but may be useful under certain limited conditions.

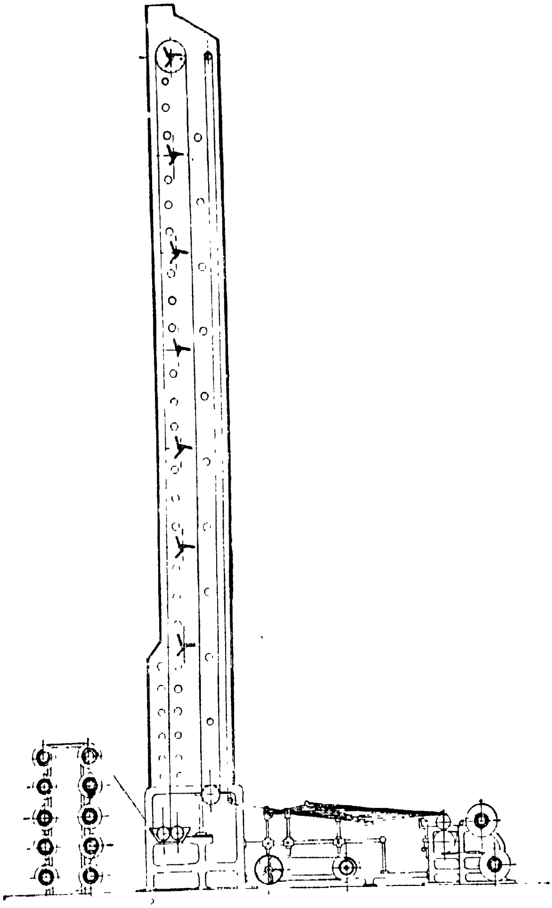


FIG. 44A.—Masurel Vertical Sizing Machine.

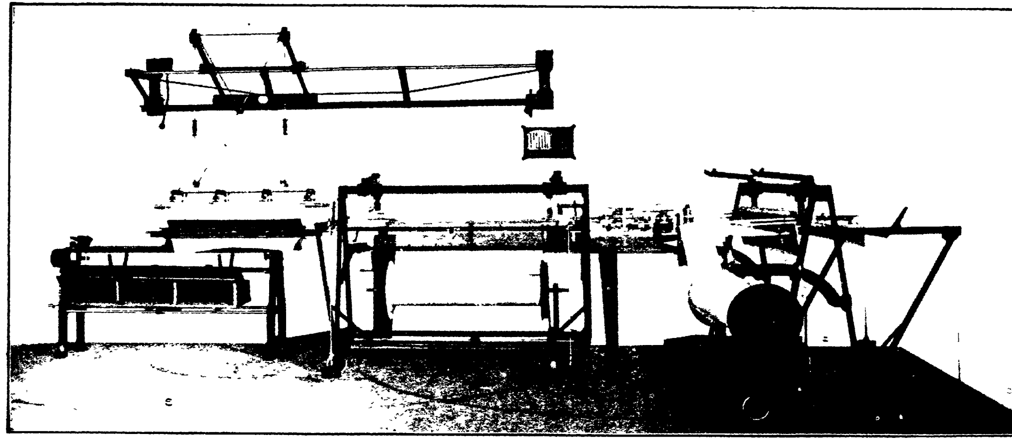


Fig. 44b.—Warp Drawing Machine.

T.

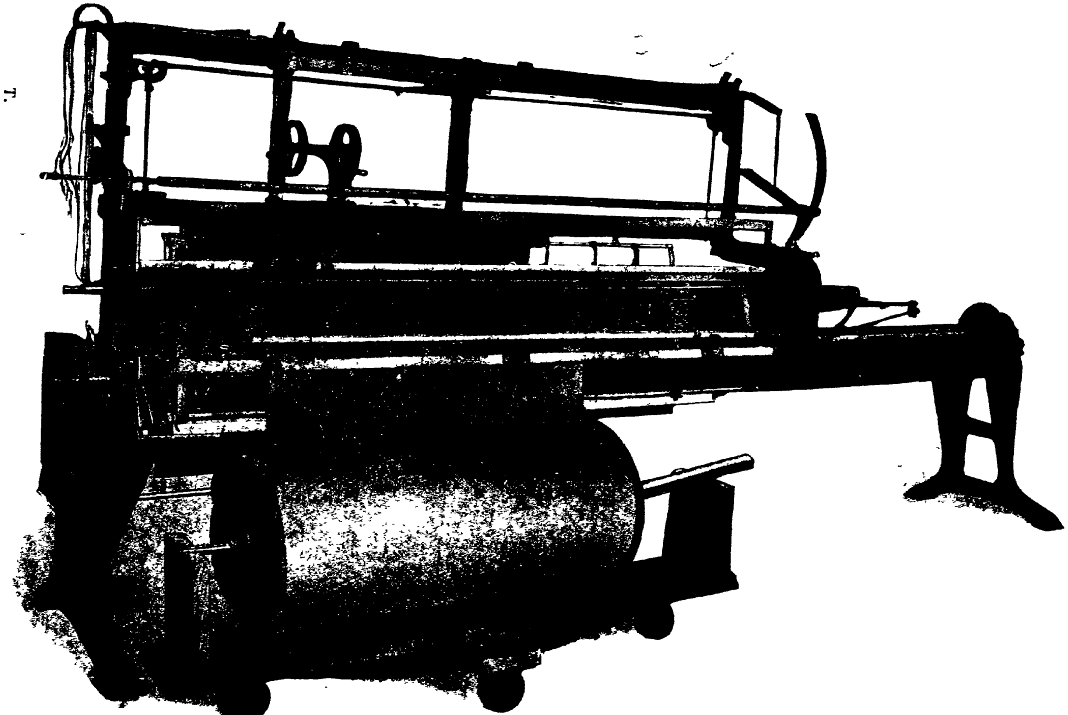


FIG. 44C.—Barber-Warp Tying Machine (Model "E")

Sizing follows warping (see Fig. 44A), the idea being to coat the thread and thus prevent its wearing flufty in the gears of the loom; and further, if possible, to strengthen the thread. In the past the tendency has always been to put vegetable size on to vegetable fibres and animal size on to animal fibres. To-day, however, the tendency is to put vegetable sizes on to every kind of material, no doubt on account of cheapness. Of course care must be taken that the vegetable size is readily extracted from the fabrics during the finishing operation, otherwise clouded pieces, owing to this irregular sizing, may result. Certain combination warping and sizing machines are placed on the market, but the call for these has rather declined than increased. Hot-air drying rather than cylinder drying is now almost universal for wool warps.

After sizing follows dressing, which consists in winding the warp at a uniform tension—both across and lengthwise —on to the loom beam. English dressers prefer to compress the warp on the beam with the tension that the warp itself will naturally stand, but American dressers often attempt to compress the warp still further in order that the warp beam may be made to carry a greater length of warp, thus saving a certain number of tyings-in.

Drawing or twisting-in follows. If the warp is to be passed through a new set of gears it will have to be drawn by hand through these. A good drawer-in working with a reacher-in passes about 1,000 to 1,200 threads per hour. Should it only be necessary to twist or tye the new warp to the warp—or "thrum" as it is called--already in the gears, this may readily be effected either in the loom or out of the loom at the rate of about 1,800 threads per hour. If the warp is plain and no precise order of coloured threads necessary, the recently

introduced "Barber-Warp Tyer" (Fig. 44c) will twist or rather tye-in a warp out of the loom at the rate of 250 knots or threads per minute.[1] This machine works on the "average" principle; thus, although almost perfect, it cannot be relied upon to maintain an absolute order of the colours in a fancy warp.

Reference may here be made to the various styles of healds put on the market. It is probable that not nearly sufficient attention is given to this section of the work, as good wearing, easily regulated, and convenient styles of healds are most necessary. Of late wire healds seem to have come much more into use, but there are good and very bad styles of wire healds, so that great care should be exercised in selecting these. Again, a shed full of wire healds means much more weight for the engine to lift.

After drawing-in, "sleying," or the passing of the threads singly or in groups of two, three, four, five or six through the reed is necessary. This is effected at the rate of about 2,000 threads per hour by means of two sleying knives worked alternately by hand. Reeds again should receive more attention than they at present claim. English reed makers can make a good ordinary article, but German and French reed makers are much ahead in the production of really fine reeds with properly feathered dents regularly soldered together.

After the warp has been passed through the gears and reed the warp-beam and gears must be lifted into the loom—the aisles in the loom shed being sufficiently wide to ensure

[1] A mechanical "drawing-in" (Fig. 44B) machine is now placed on the market. A "lease-picking" machine is also used in America to pick a lease after sizing by means of which to select the threads for tying or drawing-in.

this without damage to either warp or gears (or better still a single overhead rail laid on to transport beams and gears from the warping room direct to any loom in the shed), the gears hung in position, the reed placed in position, the warp attached to the cloth beam by means of a level wrapper, and then after the necessary gearing up the actual operation of weaving ensues.

The principal movements during weaving are as follows:

Shedding, or forming a passage for the shuttle through the warp threads, certain of the threads being definitely raised and the others depressed; threads lifted and depressed being varied for a succession of sheds.

Picking, or the throwing of the shuttle through the shed which has been formed, leaving the pick or weft-thread behind it in the shed.

Beating-up, *i.e.*, the reed beating the pick just inserted up to the cloth already formed to make a firm, even texture.

Letting-off, *i.e.*, unwrapping warp from the warp-beam to take the place of that used up in interlacing with the weft to form the cloth.

Taking-up, *i.e.*, winding up on to the cloth beam the cloth woven, this movement of necessity being worked in conjunction with the letting-off.

The following accessory mechanisms are practically necessary to ensure economical and satisfactory work:

The Boxing Mechanism, by means of which any required colour of yarn is presented, in its shuttle, on the picking plane and thus thrown into the cloth in the order required.

The Stop-Rod or the Loose-Reed-Mechanism, through which the loom is brought to a standstill should the shuttle fail to reach the box, serious breakage of warp threads thus being

avoided. The first style is applied to plain or rising box looms, the latter to circular box looms.

The Weft-fork Mechanism, which only permits the loom to go on with its work while weft is presented to it. Should the weft be broken or absent the loom is immediately brought to a standstill. There are two forms, the side-weft fork for plain looms and looms with boxes at one end only, and the centre-weft fork for double box looms.

The Warp-Stop Mechanism, by means of which the loom is brought to a standstill should any warp-thread break.

The Spooling or Shuttling Mechanism, by means of which when the cop of yarn placed in the shuttle is finished or about to be finished either it or the whole shuttle is automatically ejected and a fresh spool or shuttle pushed in to take its place in the first case without stopping the loom and in both cases without the intervention of the attendant.

Before describing certain typical looms placed upon the market reference must be made to the various methods of effecting the primary weaving movements and also to certain points of importance with reference to the accessory mechanisms.

Shedding.—To the uninitiated this may seem a simple matter requiring little consideration. Perhaps this would be so were the yarns which it is necessary to weave always strong and were time no object. But yarns must sometimes be woven which will hardly stand dressing, and looms must run from 80 up to 300 picks a minute—although a high speed is by no means always economical—and thus it comes about that most careful and detailed consideration must be given to every point in the shedding mechanism. The chief points for consideration are—firstly, the method of

selecting the healds to be raised and the healds to be lowered—absolute certainty must here be ensured; secondly, the movement of the healds to put as little strain as possible on to the warp threads during the change of shed; and

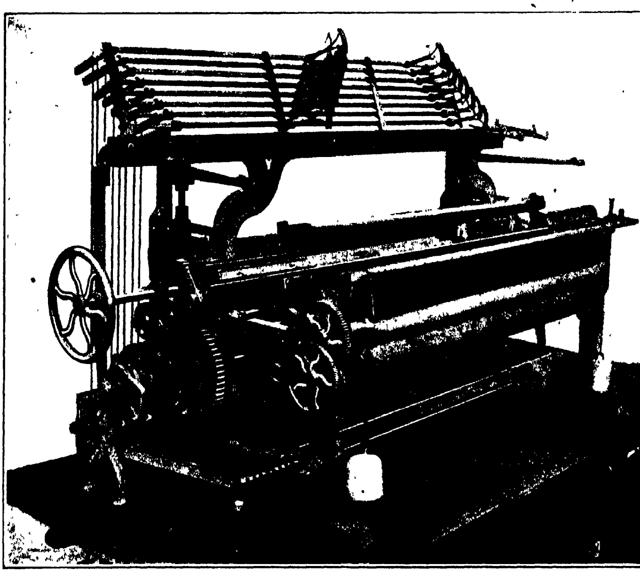


FIG. 15.—Tappet Loom with outside treading.

thirdly, the satisfactory holding of the threads up and the threads down during picking to ensure the safe passage of the shuttle. Of the varied mechanisms to effect this, the Tappet mechanism (either inside or outside tread, with "top" or "under" motion) is the simplest and most satisfactory, as the curve for the "rise" and for the "fall"

of the heald-shaft can be made to give a simple harmonic motion or any other desired motion, while the "dwell" of the heald-shaft may be regulated to a nicety (Fig. 45). There has recently been placed on the market a centre-shed Tappet which markedly tends to effect perfect interlacing of

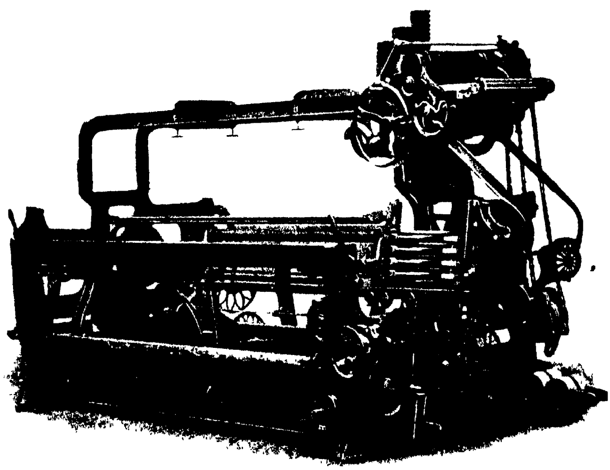


FIG. 45A.—Heavy Coating Loom.

the threads at the least possible tension. Unfortunately, the interlacing or figuring capacity of the Tappet loom is not great, so that for anything above a weave repeating on 12 to 16 shafts a Dobby must be employed, while for anything above, say, 36 shafts, a Jacquard is employed. The shedding arrangements of Dobby looms are usually in some sense an imitation of the Tappet action (see Fig. 45A), but the following variations are to be met with: close shedding and open shedding Dobbies, single-lift and double-lift Dobbies, with combinations of the

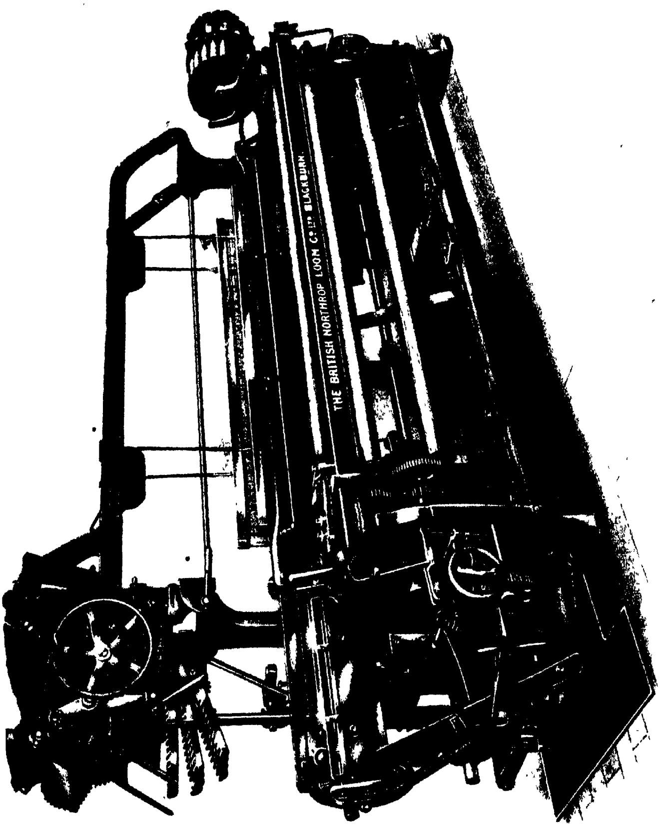


Fig. 46.—Northrop Automatic Weft Mixing Woollen Loom, with Patent Leeming Rotary and Reversible 16-Shaft Dobby.

same. Each possesses certain advantages either for the fabric being produced or in quick and perfect running. The only difference in principle between the Dobby and the Jacquard is that in the Dobby each heald-shaft may usually

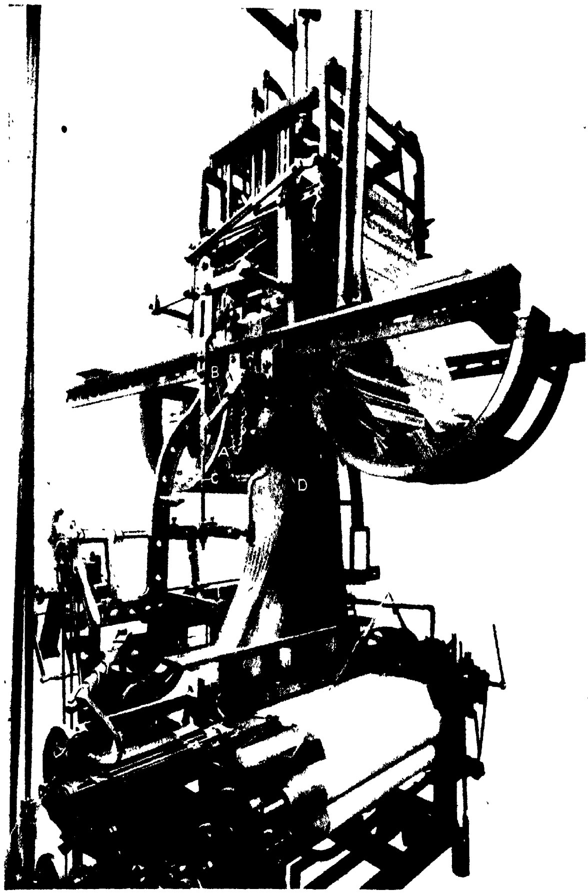


FIG. 47.—General view of a Jacquard Loom.

be controlled positively whether lifted or depressed, while

in the Jacquard the lifting only is positive, the depressing being effected by weights on the harness cords. The usual figuring capacities of Jacquards are—Bradford, 300 or 600; Huddersfield, 400; Belfast, 1,200 to 1,800; but there are naturally variations from these precise numbers in each district and for specific purposes. (See Fig. 47.)

Weaving wages largely depend upon the shaft or harness capacity of looms.

Picking.—The throwing of the shuttle through the shed—under the guiding influences of the shuttle-race and reed—is a most difficult and important matter. If thrown too strongly it is liable to break the weft yarn and to wear itself and the loom out quickly, and if thrown too weakly the loom knocks off. Again, the tendency of shuttles to fly out of the shed has necessitated the adoption of shuttle-guards to protect the weavers. There are two main types of picking motions, viz., over and under. The over-pick is the 'sweeter " and safer, but unfortunately consumes a large quantity of picking-strap. The under-pick partakes less of the slinging character than does the over-pick, so that for the weaving of lightly-twisted weft yarns such as mohair and alpaca the over-pick system possesses marked advantages.

Beating-up.—Sufficient attention is not paid to this motion by many loom makers, as the satisfactory running of the loom may largely depend upon the satisfactory running of the going-part which carries the shuttles, etc., as well as the reed. The points to be carefully considered are—sweep of crank, length of connecting pin, method of attachment of connecting pin to sword-arms, and the relationship of sword-arm connections to crank centre.

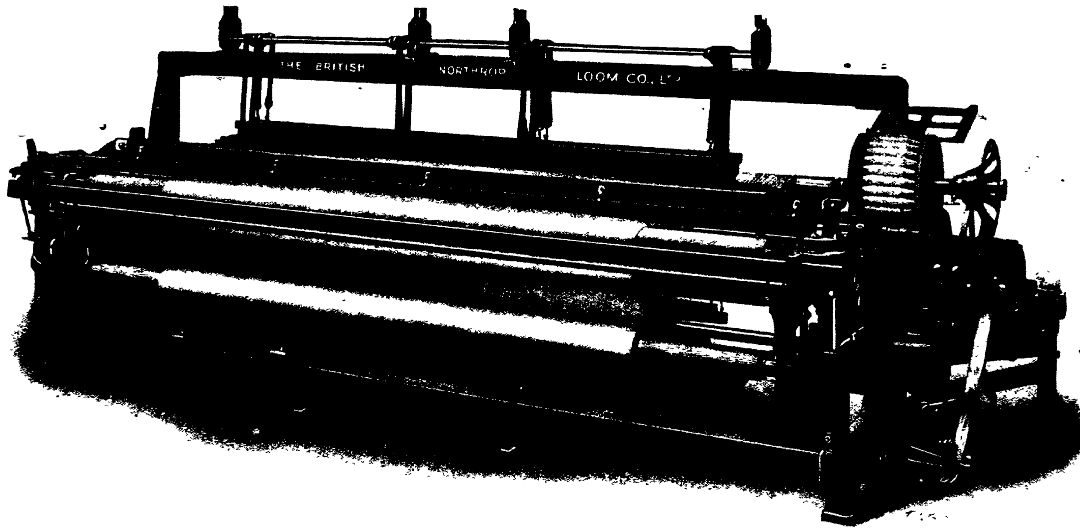


FIG. 48.—Northrop Heavy-Weight Sheeting Loom.

Letting-off and Taking-up.—These two mechanisms are usually worked in conjunction, for what the cloth requires must be delivered to it by the warp-beam. Both these mechanisms may either be positive or negative, but usually the taking-up motion is positive (so that the wefting of the cloth is perfectly controlled) and the letting-off negative. The latest form of positive letting-off motion, however, in which the tension of the warp itself regulates the letting-off, has proved a marked practical success and is nearly always adopted for heavy wefting. For lighter work and even for some forms of heavy work the ordinary or special form of negative letting-off motion is adopted. The taking-up of the cloth woven is almost invariably effected by means of a friction or sand roller (which bears upon the cloth beam, and thus turns it by friction at a fixed rate, notwithstanding its increase in circumference) driven through a train of wheels, the last one of which receives its movement from a pawl on the sword of the going-part. One or more of these wheels may be changed to give the required number of picks in specific cloths. In the best train there is a direct relationship between the picks per inch and the teeth in the change wheel.

The Boxing Mechanism.—Boxes are made in two forms—rising and falling, and circular. In rising boxes there is no limit as to size or number, while in the case of circular boxes there is a distinct practical limit in size, and it is not as a rule convenient to have more than six boxes to the round. Thus, for heavy thick materials rising boxes of great size are employed; while for fine cotton, silk, etc., the smaller circular boxes are mostly used.

Looms are made in three forms with reference to their

boxes, viz., without boxes, *i.e.*, plain looms ; boxes at one end only; and boxes at both ends. In looms with boxes at one end only there are limits in colouring, as only double picks may be inserted without very special arrangement and loss of time, while in one most important type of circular box there is a further limit as to which colours may be presented on the picking plane. Boxes at one or both sides are now largely employed in weaving solid colours to effectually mix the weft yarn and thus guard against streakiness.

The addition of boxes to a loom usually reduces its speed from 5 per cent. to 10 per cent. and necessitates the payment of a slightly higher wage to the weaver.

The Stop-rod and Loose-Reed Mechanism.—Plain and rising box looms are fitted with the stop-rod mechanism, while circular box looms are usually fitted with the loose-reed mechanism. In the stop-rod mechanism the reed is prevented from coming within less than, say, 4 inches of the fell of the cloth, unless the shuttle is in the box, by means of a stop-rod which plays against a special casting, termed the "frog." As the shuttle normally enters the box, however, it lifts this stop-rod clear of the "frog" and so the loom proceeds with its task. Should the shuttle fail to reach the box and stop in the shed, the loom is knocked-off by means of the stop-rod coming against the special casting or "frog," which, in turn, acts upon the setting-on lever and loom brake. Few or no warp threads will be broken down, as the reed cannot get nearer than about 4 inches to the fell of the cloth—a distance which is just judged sufficient to save breakage of warp threads when the shuttle is left in the shed.

In the case of the loose reed mechanism the shuttle is allowed to knock the reed out to prevent the reed breaking

the shuttle through the warp threads. To allow of this the reed is only lightly held until it is within, say, 2 inches of the cloth—when, if the shuttle had stopped in the shed, the reed would be forced out and the belt thrown on to the loose pulley—after which it is firmly locked for the beat up. Owing to this locking and unlocking of the reed heavy wefting cannot be effected by this mechanism.

The Weft-fork Mechanism.—In plain looms this is at the side, close to the setting-on handle. It consists of a small three-pronged fork passing through a grid in the going-part, across which grid the weft has to pass. If the weft be present it does not allow the prongs of the fork to pass through the grid, but, instead, tilts the fork. At this moment a hammer head is drawn back by means of a projection on the low shaft of the loom (once every two picks), but nothing happens if the weft is there and has tilted the fork. If the weft is not there, however, the fork is not tilted and a catch upon its extremity is caught by the hammer head and the loom thus brought to a standstill. Mr. Pickle, of Burnley, has patented a markedly improved form of this fork which mechanically may be considered perfect, and this cannot be said of the ordinary form.

The centre weft-fork mechanism—which must be employed when there are boxes at both ends—acts through the weft supporting if present, or allowing to fall if absent, a lightly-weighted fork, which, by means of a slide, is connected with the setting-on lever.

The Warp-stop Mechanism.—While the weft-stop mechanism has always been considered as essential to the satisfactory running of a loom, the warp-stop mechanism has never been in favour, and obviously it can only be of

economical value in the case of weaving tender warps (when possibly it helps to break down threads) or where one attendant looks after a large number of looms. With the comparatively recent introduction of the automatic loom, warp-stop methods have increased in favour, but their application in anything but very plain work is still comparatively rare.

There are two forms placed on the market—the mechanical and the electrical. The chief objection to them is the time taken in readjustment when drawing in a new warp, while, of course, it is conceivable that they may in all warps occasionally cause ends to break down. Possibly the greatest advantage lies in that a weaver cannot produce an imperfect piece as the loom will not run with ends down.

The Spooling or Shuttling Mechanism.—This is the mechanism of most recent introduction, although so called automatic looms were tried about forty years ago. If one weaver is to attend to sixteen or twenty-four looms, it is evident that there must be some self-shuttling arrangement, or there will always be some looms standing. On the other hand, the additional mechanism involved may necessitate additional attention on the part of the tuner or overlooker—usually a high-wage man—and hence he will not be able to follow so many looms.

In both the wool and the cotton trade the Northrop loom (Figs. 46, 48 and 49)—one form of the automatic loom—is being largely adopted. The spool ejecting mechanism in the cotton loom was brought into play by the weft running off, so that each change of spool was accompanied by a broken pick in the piece. This broken pick would be a serious defect in cloths other

extra value, may be added to worsted coatings by such a weighting agent as chloride of zinc. These, however, may be taken to be the exceptions which prove the rule. Most cotton goods are improved and rendered more sightly by either adding filling or by smoothing down the size already present in the warp yarn. Linen goods specially lend themselves to, one might almost say, "showing-off" a filling agent "starch"—in fact, it is quite questionable whether the goods should not be placed in the second class. Some certainly should; others are not abnormally "filled." Silks, being frequently woven in the "gum," must be discharged in finishing; but it is probable that the presence of a small amount of silk gum in the bath and on the fibre is necessary to preserve the best characteristics of the texture under treatment.

Finishing Processes and Machines.—As many processes and machines are common to all the recognised fabrics, such may be described generally prior to a particular description of the finishing operations necessary for representative fabrics.

Mending, Knotting and Burling.—This consists in repairing the broken threads and picks nearly always present in the fabric as it leaves the loom. It is also advisable to mend pure worsteds after scouring, as the faults are then more easily seen. The mending wage for fine worsteds is frequently equal to the weaving wage. Knotting and burling are also carried out at this stage.

Scouring.—This consists in thoroughly cleansing the fabric prior to proceeding with the finishing proper. Certain cotton, cotton and wool, and silk cloths are so clean on leaving the loom that the finishing proper is at once

proceeded with. Many wool goods, however, must be scoured fairly clean in what is known as the "dolly" or on the five-hole machine, before they will satisfactorily take the finish for which they are designed. Again, colours running in the scouring may often be scoured out, while if left in for the milling they will truly "bleed" and permanently stain the neighbouring threads and picks.

Milling.—This operation is equivalent to hammering or squeezing the cloth until it has attained to a sufficient solidity. Wool only of all the textile fibres "felts," as it is termed, so that this operation is practically limited to wool or wool combination goods.

Two machines are employed to effect the required felting, yielding somewhat different results. The milling stocks, imitating the original treading action of the human feet, hammer the cloth (which is placed in a holder or receptacle so shaped that the falling of the hammer not only "mills" or "felts" but also turns the cloth round so that its action is evenly distributed over all its surface). The action of the stocks is obviously of a bursting nature, giving "cover" on the fabric.

The "milling machine" works on the squeezing basis, the cloth to be milled being squeezed up in lengths or in width or both according to requirements. This machine not only gives a more solid cloth, but also enables the miller to control the width and length and consequently the weight per yard.

Crabbing.—This is an operation based upon the fixing qualities of wet heat as applied to various textures, and upon the desirableness of the first shrinking and consequent setting of the fabric being very carefully controlled. The

fabric to be "crabbed" is wound dry and perfectly level on to a roller and then under tension wound on to a roller running in hot water. From this roller the fabric may be run to another roller under similar conditions. There are various forms of crabbing machines, but the factors are always the same—wet heat and tension and weight.

A very useful but somewhat dangerous machine is used for finishing certain cotton warp and wool weft goods, consisting of four or five rollers running in scouring and washing-off liquors, round which the fabric is passed, followed by a series of drying rollers, so that the fabric in a sense is continuously scoured, crabbed and dried. This machine is dangerous in that "crimps" are not eliminated as in the case of true crabbing. Of course this machine may be employed in conjunction with the crabbing machine when the above objection does not hold.

A special crabbing machine employed in the woollen and worsted trade simply arranges for steaming while the fabric is being wound on to a true steaming roller upon which the fabric may be steamed and cooled off; or it may be wound on to a roller for "boiling" if necessary.

Steaming.—If the fabric is to be steamed it is run from the last crabbing roller on to the steaming roller—a hollow roller with a large number of holes pierced from its central tube to its periphery—so that steam may be blown right through the piece. The piece is usually re-wound inside out and re-steamed to ensure level treatment. It is then allowed to "cool off." The basis of this treatment appears to be a "setting" action, owing to the great heat employed no doubt partially dissolving or liquefying certain of the

constituents of the wool fibre. Prolonged steaming undoubtedly weakens wool fibres.

Dyeing.—From a mechanical point of view dyeing may be conducted on either the "open width" or "rope" method. Cotton goods, for example, must be piece dyed on the "jigger" full width if level shades are to be obtained, while wool goods are usually satisfactorily dyed in rope form. There is no satisfactory theory for this, but practically as fact it is a most important matter. Mercerized cotton has such an affinity for dyes that the utmost difficulty is experienced in finding a restrainer to effect the even distribution of the dye in light shades. Without some restraining influence the first few yards might take up the whole of the colouring matter.

Most goods must be opened out after dyeing, as if allowed to cool in a creased state they retain their creases. The point here to note is that to take out a crease it requires a greater heat than the heat at which the crease was put into the piece.

Washing-off.—This is a simple operation to ensure that all the unfixed colouring matters, etc., are cleaned out of the piece. As the action is mechanical, cold water may be employed.

Drying.—This is usually effected by passing the fabric round a series of steam-heated rollers. Owing to the way in which the fabric is wrapped round these rollers it never rests for long upon one roller, so that it cannot be burnt; again it is wrapped alternately face and back upon the rollers, so that it is really dried in the shortest possible time. In goods which may be worked by a straight pull on the warp either horizontally or vertically arranged drying

rollers are ample; but if any extension in width is desired a tentering machine must be employed. As previously explained, these drying rollers are usually arranged in conjunction with another operation—say, continuous scouring and crabbing. Of late there has been a most marked tendency to hot-air dry.

Tentering.—This consists in holding the cloth tightly in the warp direction and widening it in the weft direction. To effect this the cloth is pinned by hand on to two continuous tenter chains, which as they carry the cloth into the machine gradually increase the distance between them, thus tentering out the cloth. The "give" of the cloth is probably due to three factors, viz., give in the fabric structure, in the thread structure, and in the fibre itself. Obviously, unless the cloth is "set" in this position it will more or less shrink after the process. To effect the setting the cloth must be fed into the machine damp; in this condition it must be widened or straightened out, and then in the widened out condition it must be dried. In the most approved tentering machines the expanding chains carry the fabric over gas jets which just supply the necessary heat for drying. A steam-jet pipe is also provided to damp the cloth just prior to or during tentering to give it the necessary plasticity. In the enclosed "steam-pipe" type of machine the efficiency of the machine is often impaired by the difficulty of getting away the hot moisture-charged air, but as drying largely depends upon this and not so much upon the heat developed, this must be done if efficient and economical working is to be attained.

It will be evident that goods "tentering out" will have a tendency to shrink. London tailors are credited with

always testing the natural shrinkage of these goods by folding them with a thoroughly wetted and wrung out cloth for a day or two, and then noticing the shrinkage which has taken place. Goods so treated are spoken of as "London shrunk."

Brushing and Raising.—After scouring, milling, etc., most wool goods and some few others present a very irregular face, neither clear nor yet fibrous. If a clear face is desired the few fibres on the face must be raised as much as possible in order that they may be cropped off in the cropping or cutting operation which follows. To effect this the face of the fabric is regularly presented to the action of a circular brush or to the action of "teazles."

Should a fibrous face be desired—technically termed a "velvet" face—the fabric must be raised wet on what is termed the "raising gig" from head to tail, from tail to head, and across if possible, to obtain a sufficiently dense fibre, naturally somewhat irregular in length.

The "raising gig" proper carries teazles, which without damage to the foundation of the fabrics submitted to them raise a sufficiently dense pile. For flannelettes and some other goods a stronger machine is required; in this case wire teeth, specially constructed and specially applied, take the place of the teazles. Teazles themselves vary much in raising qualities; and the experienced raiser knows this and takes advantage of it.

Cropping or Cutting.—To obtain a perfectly level face on fabrics they must be submitted to a "cropping" or "cutting" operation. Formerly cropping was more or less efficiently done with large shears, but to-day much better and more accurate work is done by the circular

"cropper," which, working on the principle of the lawn-mower, may be set to leave a pile of any required length, or if desirable to practically leave the fabric bare. The cutting action is due to the combined action of the fixed bed and the spirally arranged revolving blades.

Singeing.—Some fabrics, such as Alpacas, Mohairs, etc., are required to have a clear lustrous face such as no cropping machine can possibly leave. Singeing must here be resorted to. The fabric to be singed is quickly passed face downwards over a semi-circular copper bar heated to almost white heat. The speed of the cloth naturally decides to a nicety the amount of singeing effected, but to avoid damage to the fabric a quick speed is usually adopted and the fabric passed over, say, six times. Gas singeing is not extensively applied save in genapping, *i.e.*, singeing and clearing braid, etc., yarns.

Pressing.—By means of the hydraulic press great weight may be put on to fabrics, and they may thus be more or less permanently consolidated and in some cases lustred. Heat may be applied in the press, thus aiding in the fixing of the fabrics under treatment.

Presses are practically made in three forms: ordinary, intermittent, and continuous. The ordinary press simply receives its charge of cloths in the ordinary cuttled form, heat being introduced through the expanding or contracting press-plates separating individual pieces. Press papers are placed between the cuttles of the pieces to form the surface against which the fabric is pressed.

In the intermittent form about five yards is treated at once, suitably pressed and held stationary in the heated machine for, say, a minute, and then automatically moved

on so that the ensuing section of the fabric may be treated in like manner.

In the continuous form the pressing is continuously effected.

The time factor naturally varies in all three forms, and is naturally the factor which decides which is the most efficient machine for particular classes of goods.

Calendering.—This operation simply consists in passing goods through heavily weighted and if desirable heated rollers which it is found break or render less "caky" fabrics passed through them. The probable action is to distribute rigidity or solidity.

Schreinering.—This operation consists in passing suitably constructed cloths between a pair of solid heavily weighted steel rollers, one of which has a plain papier-mâché surface and the other is ruled with extremely fine lines from 190 to 500 to the inch. The effect on the piece is to develop a really wonderful lustre specially applicable to mercerised cotton goods.

Filling.—As already remarked, it may be desirable or necessary to stiffen some goods to increase their utility. Again, some goods are "filled" simply to attain a desired weight.

Soap or other agents may be cracked in pieces or the pieces may be definitely impregnated with some such agent as chloride of zinc. It is hardly necessary to add again that filling is rarely legitimate.

Conditioning.—After fabrics have passed through a process involving the application of dry heat—such as singeing—they are unnaturally dry, and as a consequence are very weak. To give back the natural moisture, goods in such a

condition are passed through a machine which "sprays" them and thus causes the fabric to quickly regain the moisture and often the strength lost.

The foregoing are the principal operations in finishing. The secondary operation such as hydro-extracting, burl-dyeing, extracting, etc., are of such minor importance that there is no need to specially refer to them here.

Waterproofing.—Fabrics may be rendered water-proof in three distinct ways. Firstly, the fibres of which they are composed may be rendered moisture-repellent, as, for instance when wool is subjected to the action of super-heated steam. Secondly, the fibres may be charged with a water-repellent substance, which thus prevents the passage of water save under pressure. Oiled fibres, for instance, possess this characteristic. In these two cases the surface tension of the liquid which endeavours to pass through the fabric plays an important part. Thirdly, the fabric may be "plastered" or entirely coated with some such agent as india-rubber.

All three methods are employed, and there are, of course, combinations which are not precisely one or the other.

General Notes.—To give an idea of how the foregoing operations are applied in finishing specific types of fabrics the six following lists are given:—

WOOLLEN CLOTH. (All Wool.)	WORSTED CLOTH. (All Wool.)	LINING FABRIC. (Cotton and Wool.)
Mending, Burling, etc.	Mending, Burling, etc.	Mending.
Soaping.	Crabbing.	*Crabbing.*
Scouring.	Soaping.	Steaming and Setting.
Milling (Stocks)	Scouring.	Dyeing.
Milling (Machine).	Mending.	Washing-off.
Washing-off.	Light-milling.	Tentering and Drying.
Hydro-extracting.	Washing-off.	Singeing (several times).

WOOLLEN CLOTH.
(All Wool.)

Crabbing.
Tentering and Drying.
Brushing and Dewing.
Raising.
Cropping.
Brushing and Steaming.
Cutting.
Pressing.
Steaming.
Cuttling.

WORSTED CLOTH.
(All Wool.)

Hydro-extracting.
Crabbing.
Tentering and Drying.
Dewing or Conditioning.
Brushing and Raising.
Cropping.
Brushing
Dry Steam Blowing.
Cuttling, Rigging.
Folding and Measuring.
Pressing.

LINING FABRIC.
(Cotton and Wool.)

Washing-off or Conditioning.
Tentering.
Pressing.

SILK FABRIC.[1]
(Net Silk.)

Singeing or Cropping.
Discharging and Washing.
Drying.
Cylindering.
Damping, or
Dressing and Singeing.
Calendering and Lustring.
Rolling or Plaiting.
Pressing.

COTTON FABRIC.[1]
(Calico.)

Singeing.
Souring.
Washing.
Saturating with Caustic Soda.
Kier Boiling
Washing.
Chemicing.
Washing.
Souring.
Washing
Squeezing.
Mangling.
Drying.
Filling.
Drying.
Damping.
Stretching.
Beetling or Calendering.
Making-up.

LINEN FABRIC.[1]
(Standard Style.)

Lime-boiling.
Washing.
Souring.
Washing.
1st Lyre boil.
Washing.
Chemicing.
Washing.
Souring.
Washing.
2nd Lyre boil.
Washing.
Grassing.
Chemicing.
Washing.
Souring.
Washing.
Scalding.[2]
Washing.[2]
Chemicing.[2]
Washing.[2]
Souring.[2]
Washing.[2]
Scutching.
Water-mangling.
Starching and blueing.
Beetling.
Breadthening.
Calendering.
Lapping.

[1] These details are supplied by specialists in the respective branches of the industry. All are preceded by operations equivalent to Mending, Burling, etc.

[2] These processes must be varied in accordance with particular requirements.

The foregoing lists seem fairly comprehensive, but in reality they by no means convey a complete idea of the many different styles of finish. For woollen cloths, for example, some half-dozen typical and distinct finishes could be cited, and the other styles are by no means without their varieties (see Fig. 53F).

There can be no doubt but that more attention to the effects of "finish" is much to be desired. To thoroughly demonstrate the influence of each specific process the best method is to pass a suitable length of fabric through the necessary or desirable operations, and to cut off, say, a yard length from the fabric after each operation as a reference. Thus for a piece-dyed Botany coating reference lengths should be preserved of (*a*) warp and weft; (*b*) grey cloth; (*c*) scoured cloth; (*d*) milled cloth; (*e*) dyed and tentered cloth; (*f*) raised cloth; (*g*) cut cloth; (*h*) steamed cloth; and (*i*) pressed cloth. The record of all the foregoing reference samples should include (1) counts of warp and weft; (2) threads and picks per inch; (3) length and width; (4) weight; and (5) strength. Such records as these have been worked out in the Testing Laboratories of the Bradford Technical College during the past six to eight years, and are found to add most markedly to the efficiency, value and interest of the investigations undertaken.

CHAPTER X

TEXTILE CALCULATIONS

In a general sense most textile calculations have, and should have, reference to the ultimate cloth produced. It is true that there is a distinct "wool" trade, a distinct "top" trade, and a distinct "yarn" trade, each of which is in a sense independent of the cloth trade. It is nevertheless obvious that all nomenclature, designation and indication should be on some basis readily understood and easily applied by the cloth constructor.

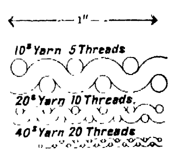


FIG. 19.—Illustrating the Setting of Fabrics; also the Weights of Fabrics.

Unfortunately the "science of cloth construction" was developed so late that not one but many cumbersome methods had long been firmly established, so that to-day a considerable portion of the designer's and cloth-coster's time is wasted on calculations which, with full cognisance of all possible conditions, might easily have been eliminated by the adoption of convenient standard systems for counts of yarn, sets, etc.

Starting from the cloth it is evident that the most useful designation for yarns would be in fractions of the inch (or of a decimeter). Thus 1's yarn would have a diameter of 1 inch, 2's of $\frac{1}{2}$ inch, 3's of $\frac{1}{3}$ inch, 4's of $\frac{1}{4}$ inch, and so on,

or that 1, 2, 3, 4, etc., threads might be laid side by side in an inch. The "set" calculations for cloths on this basis would be very simple. On this basis, as shown in Fig. 49, with plain weave, a 10's yarn would be set five threads per inch, a 20's yarn ten threads per inch, and a 40's yarn twenty threads per inch. Moreover, on this system, the weight of the cloth would vary in inverse proportion to the counts, for, as shown, the cloth with 20's count is half the thickness or weight of the cloth with the 10's count, the cloth with 40's count is half the weight of the cloth with 20's count, and *vice versâ*. If the 10's count cloth was a 30 oz. cloth, the 20's count cloth would be a 15 oz. cloth, and so on. Again, the "sets" or threads per inch and picks per inch for any given weave or interlacing would be simplicity itself. As shown in Fig. 50, for example, the threads and picks per inch would be—

$$\frac{\text{Counts of yarn} \times \text{threads in repeat of weave.}}{\text{Threads} + \text{intersections in repeat of weave.}}$$[1]

Thus with a 60's yarn in $\frac{2}{2}$ twill the set should be—

$$\frac{60 \times 4}{6} = 40 \text{ threads and picks per inch.}$$

Of course the practical designer would slightly vary the set in accordance with the material he was using; if rough and slackly twisted he would probably put 38 threads per inch, while if smooth, compact and hand-twisted, he might put 42—44 threads and picks per inch. He would also probably take into account the effects of finish, and, of

[1] This is a fairly accurate approximation for ordinary fabrics in which warp and weft bend equally. Note that it is only applicable in this form if count equals the diameter of the yarn.

course, the handle of the ultimate texture he hoped to produce.

Unfortunately this simple system is quite out of count, firstly, because yarn counts designate length and not diameter; and secondly, because yarn and set numbers vary in different localities.

Undoubtedly in the early days of the textile industry yarns were spun very irregularly and to unknown counts in any and every denomination. Then the idea of spinning a definite weight of wool, say 6 lbs., to a given length of yarn, so that a given length of piece could be got out of it, would impress itself upon the more thoughtful spinners. Thus the Leeds "wartern" is 6 lbs., and if the yarn was spun to 1,536 yards, or 1 yard per dram, it was called 1's count, if to 2 yards per dram, 2's count, and so on. In most localities, however, the unit of 1 lb. would be naturally adopted as the weight. Unfortunately there was not the same unanimity with reference to the length. To number 1 yard to 1 lb. 1's count, 2 yards to 1 lb. 2's count, 20 yards to 1 lb. 20's count would be out of the question, as a very thick yarn would then have 256 as its number, and a fine yarn, say, 2,560 as its number. To reduce this count number to thinkable and workable

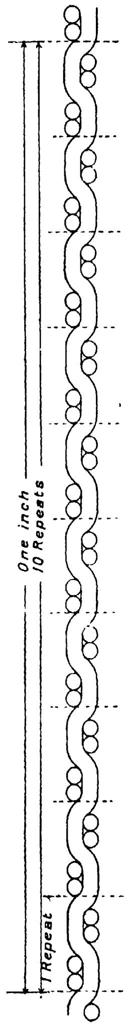


FIG. 50.—Illustrating the Setting of Fabrics.

proportions, in some cases the weight was reduced,[1] and in others the system of "hanking" was resorted to. But the localized character of the various industries unfortunately resulted in a varying weight and a varying number of yards per hank being adopted. In most count systems the hanks per lb. (avoirdupois) indicate the count. Thus 20's count equals 20 hanks per lb., 30's count equals 30 hanks per lb., and so on. But the cotton hank is

LIST IX.—VARIOUS SYSTEMS OF COUNTING YARNS.[2]

Length constant. Weight variable.

System.	Weight.	Length of Hank.	Yards per hank × count, × by gauge point = yards per lb.
Cotton	1 lb.	840 yards	× 1
Worsted	1 lb.	560 yards	× 1
Linen and Hemp	1 lb.	300 yards	× 1
Raw Silk	1 oz.	Number of yards	× 16
Dewsbury	1 oz.	Number of yards	× 16
Yorkshire Skeins Woollen	6 lbs.	1,536 yards	× ·16
Galashiels	24 oz.	300 yards	× ·66
Hawick	26 oz.	300 yards	× ·61
Stirling and Alloa	24 lbs.	Cuts Yds. 48 × 240 (Spindle)	× ·04
West of England	1 lb.	320 yards	× 1
German wool count	½ kilog.	2,200 Berlin ells	
Run (American)	1 oz.	100 yards	× 16
Cut (American)	1 lb.	300 yards	× 1
Metric	1 kilog.	1,000 metres	× ·45
French Metric	½ kilog.	1,000 metres	× [illegible]

[1] The Yorkshire system may be said to be based upon the yards per dram, and there is also a system based upon yards per ounce, and 1,000 yards per ounce.

[2] See Bradbury's "Calculations in Yarns and Fabrics."

840 yards;[1] the worsted, 560 yards; the linen, 300 yards; Yorkshire woollen skein, 256 yards; West of England, 420 yards; and Galashiels, 300 yards for 24 oz.; so that further complexity has thus been introduced. With the table accompanying, however, the yards per lb. in any denomination may readily be found, and from the yards per lb. any weight or diameter calculation readily worked out.

LIST IXA.—VARIOUS SYSTEMS OF COUNTING YARNS.[2]

Length constant. Weight variable.

System.	Unit of Length.	Unit of Weight.	Count
Halifax Rural District	80 yards	Dram	
Jute, Heavy Flaxes and Hemp	Cuts Yds. 48 × 300 (Spindle)	lb.	
Denier System . .	Raw silk (176 metres or 520 yards)	Denier	
Dram System . .	1,000 yards	Dram	Repeats of unit weight in unit length = the counts.
International Denier .	500 metres	½ decigramme	
Legal Silk count appd. in Paris, 1900	450 metres	½ decigramme	
American Grain .	20 yards	Grain	

Curious to relate, the √ of the yards per lb. of any material (with a suitable allowance of from 5 to 15 per cent.)

[1] No doubt originating from a reel of a convenient circumference, with a convenient number of warps upon it.

[2] See Bradbury's "Calculations in Yarns and Fabrics."

gives the approximate working diameter of any yarn. Working backwards diameter^2 = the area of a square, and the area of a square varies inversely to length ; therefore the diameter varies inversely as the $\sqrt{}$ of the length, and as count of yarn is in proportion to length therefore *the diameter of a yarn varies inversely as the $\sqrt{}$ of the counts* (that is denomination being the same).

This accounts for the relationship of diameter of yarn and lengths or counts, but not for the $\sqrt{}$ of the yards per lb. being the actual numerical diameter in fractions of an inch. This coincidence suggests that there is some method in the madness of the English lb., yard and inch, and that they are not merely haphazard standards. If the metric count system is adopted the $\sqrt{}$ metres per kilogram $\times$ 2·4 = the threads per decimeter, the decimeter being the most convenient unit to adopt for sets.

The most important systems of counting yarns with length constant and weight variable are given in List IXA.

In the foregoing particulars the inch is taken as the basis. Unfortunately the inch has been taken as the basis in very few manufacturing districts. The reason for this is not far to seek. Bradford, for instance, apparently based its set particulars upon the yard, Leeds upon the ¼ yard or 9 inches; Blackburn upon 1¼ yards; while possibly other districts, owing to French and Flemish immigration, based their sets upon the Flemish ell or French aune—¾ yards or 27 inches—which later possibly being converted into terms of the yard, would create further confusion.

But this is not all. It was evidently found convenient to

warp with a given number of threads. In Leeds thirty-eight (termed a "porty") were employed; in Bradford forty (termed a "beer"), and so on. Thus it became customary for the set of a fabric to be defined by the number *of times the threads* warped with repeated in the standard width. Thus the Leeds "set" is the "porties" per quarter (9 inches)," the Bradford set the "beers per 36 inches or one yard." So little impregnated with scientific method are the textile industries even to this day that these very local standards are still in full use. Thus the man who speaks of threads per inch in Bradford or Leeds mills speaks in an unknown tongue, and is not in the least understood. Of course there is a tendency to reduce these sets to the threads per inch standard. Thus the Bradford man sometimes states the Bradford set as being based upon $1\frac{1}{9}$ threads per inch; but even he is an exception and usually there is not the slightest endeavour to make the inch the standard; in fact, there is antagonism of a somewhat violent character against any change.

The following are the principal set systems with their gauge points for finding the threads per inch (see List X., p. 212).

Some of the most difficult calculations and also some of the easiest possible calculations which the textile designer has to work out have reference to the weight per yard of the fabrics with which he deals. In the worsted coating and the woollen trade the weight per yard (usually 54 inches × 36 inches) is the basis of all dealings; in the stuff, cotton and other trades, although often stated, it is by no means so important. Now under simple conditions of yarns and

gives the approximate working diameter of any yarn. Working backwards diameter^2 = the area of a square, and the area of a square varies inversely to length; therefore the diameter varies inversely as the $\sqrt{}$ of the length, and as count of yarn is in proportion to length therefore *the diameter of a yarn varies inversely as the $\sqrt{}$ of the counts* (that is denomination being the same).

This accounts for the relationship of diameter of yarn and lengths or counts, but not for the $\sqrt{}$ of the yards per lb. being the actual numerical diameter in fractions of an inch. This coincidence suggests that there is some method in the madness of the English lb., yard and inch, and that they are not merely haphazard standards. If the metric count system is adopted the $\sqrt{}$ metres per kilogram $\times$ 2·4 = the threads per decimeter, the decimeter being the most convenient unit to adopt for sets.

The most important systems of counting yarns with length constant and weight variable are given in List IXA.

In the foregoing particulars the inch is taken as the basis. Unfortunately the inch has been taken as the basis in very few manufacturing districts. The reason for this is not far to seek. Bradford, for instance, apparently based its set particulars upon the yard, Leeds upon the ¼ yard or 9 inches; Blackburn upon 1¼ yards; while possibly other districts, owing to French and Flemish immigration, based their sets upon the Flemish ell or French aune—¾ yards or 27 inches—which later possibly being converted into terms of the yard, would create further confusion.

But this is not all. It was evidently found convenient to

warp with a given number of threads. In Leeds thirty-eight (termed a "porty") were employed; in Bradford forty (termed a "beer"), and so on. Thus it became customary for the set of a fabric to be defined by the number of times the threads warped with repeated in the standard width. Thus the Leeds "set" is the "porties" per quarter (9 inches)," the Bradford set the "beers per 36 inches or one yard." So little impregnated with scientific method are the textile industries even to this day that these very local standards are still in full use. Thus the man who speaks of threads per inch in Bradford or Leeds mills speaks in an unknown tongue, and is not in the least understood. Of course there is a tendency to reduce these sets to the threads per inch standard. Thus the Bradford man sometimes states the Bradford set as being based upon $1\frac{1}{9}$ threads per inch; but even he is an exception and usually there is not the slightest endeavour to make the inch the standard; in fact, there is antagonism of a somewhat violent character against any change.

The following are the principal set systems with their gauge points for finding the threads per inch (see List X., p. 212).

Some of the most difficult calculations and also some of the easiest possible calculations which the textile designer has to work out have reference to the weight per yard of the fabrics with which he deals. In the worsted coating and the woollen trade the weight per yard (usually 54 inches × 36 inches) is the basis of all dealings; in the stuff, cotton and other trades, although often stated, it is by no means so important. Now under simple conditions of yarns and

set there is no difficulty in calculating the weight of a piece. The calculation simply stands—

$$\frac{\text{Yards of yarn in piece}^{1}}{\text{Yards per lb. of yarn employed}} = \text{lbs. weight of piece,}$$

$$\text{and } \frac{\text{lbs. of cloth} \times 16}{\text{length of cloth in yards}} = \text{oz. per yard.}$$

LIST X.—VARIOUS SYSTEMS OF INDICATING THE SET.

Locality and System.		Standard width in inches.	Number of Threads in one Beer, Portie, etc.	Given Set to find ends per inch.
Yorkshire	Bradford	36	40	× 1·11
	Leeds	9	38	× 4·22
	Huddersfield and U.S.A.	1	Splits per inch × ends in splits.	
	Dewsbury	90	38	× ·422
Lancashire	Bolton	$24\frac{1}{4}$	10	× 1·64
	Blackburn	45	40	× ·9
	Manchester	36	2	× ·055
	Stockport	2	2	× 1
Scotch	Glasgow	37	2	× ·051
	Tweed	37	40	× 1·08
Belfast and North of Ireland	Linen Plain, etc.	40	2	× ·05
	,, Damask	30	40	× 1·33
	,, ,,	37	2	× ·051
	,, ,,	Ends per inch × reed width.		
	Silk	Width of fabric, number of ends in each split.		

There are, however, a few complications likely to arise. Yarn counts may be in two or more denominations, threads of various counts or thicknesses may be twisted together

[1] This further extended is:

$$\frac{\text{Threads per inch} \times \text{width in loom} \times \text{yards long of warp}}{\text{Warp counts} \times \text{hanks per lb.}} +$$

$$\frac{\text{Picks per inch} \times \text{width in loom} \times \text{yards long of cloth}}{\text{Weft counts} \times \text{hanks per lb.}} = \text{lbs. of cloth,}$$

to form part or the whole of either warp or weft, warp and weft may be composed of several colours, there may be differences in shrinkage and loss in weight of warp and weft during finishing, and other disturbing influences of a less pronounced type. All the foregoing influences, with one exception, are either so easy of comprehension or are necessarily so dependent upon practical conditions that no attempt need be made to deal further with them here. The exception is the twisting together of yarns of varying thicknesses. For instance, what is the "count" of a 40's cotton twisted with a 40's cotton; a 30's cotton twisted with a 40's cotton, and a 30's cotton twisted with a 60's worsted?

There are really four methods of working out such problems as these.

1st Method.—Base the calculation upon a yard of each material being twisted together.

Thus the first calculation will stand—

$$\frac{1 \text{ lb.}}{40 \times 840} + \frac{1 \text{ lb.}}{40 \times 840} = \frac{1}{16,800} \text{ of } 1 \text{ lb.}; \textit{ i.e.}, 1 \text{ yd.} = \frac{1}{16,800} \text{ of } 1 \text{ lb.} \therefore 1 \text{ lb.} = 16,800 \text{ yards} = \frac{16,800}{840}$$

$= 20$'s cotton counts.

2nd Method.—Work upon the L. C. M. of the number, take this as the length in hanks and proceed as before.

Thus the second calculation will stand—

L. C. M. of 30 and 40 = 120 hanks as length for combination.

$$\frac{120}{\frac{120}{30} + \frac{120}{40}} = \text{hanks per lb.} = \text{counts.}$$

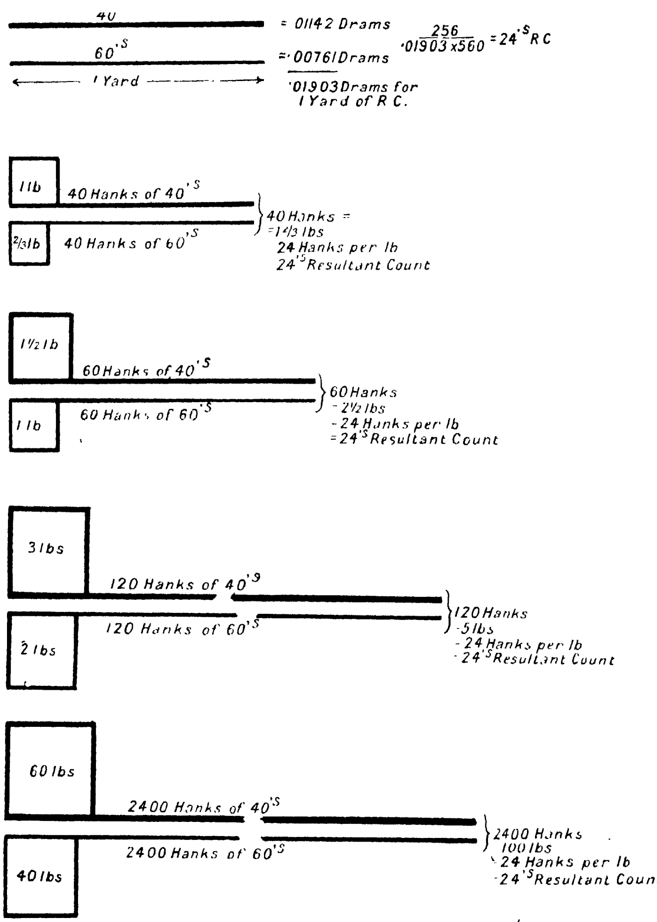


FIG. 51.—Graphic Illustration of the Resultant Counts of Twisting together two Threads of Different Counts.

This is better stated as follows—

Hanks.		Lbs.
$120 \div 30$	=	4
$120 \div 40$	=	3

120 weighing 7 = 17 hanks per lb. or 17's counts.

3rd Method.—Work by means of the suitable, if somewhat large numbers, found by multiplying the two count numbers together.

Thus the third calculation will stand—

$$(60\text{'s worsted} = \frac{60 \times 2}{3} = 40\text{'s cotton}),$$

$30 \times 40 = 1{,}200$ hanks.

$$\frac{1{,}200}{\frac{1{,}200}{30} + \frac{1{,}200}{40}} = \text{hanks per lb.} = \text{counts.}$$

The second method seems so much more covenient than the other two that it is most desirable to adopt it whenever possible. Its convenience is all the more marked when the prices of the yarns are given and the price per lb. of the resultant count is required; and again when three or more yarns are to be folded together. Such calculations are so simple in the light of the foregoing that it is not considered necessary to treat them further here (see graphic illustrations).

The changing of the weights of cloths presents one or two features which are somewhat curious and should be specially noted. For instance, to make cloths lighter—(*a*) Warp may be kept the same, and a thinner weft or fewer picks per inch of the same weft may be inserted; or if the cloth is

built on the square (*b*) the whole structure of the cloth may be changed and *more* threads and picks per inch may be inserted of a finer yarn. The explanation of this seemingly contradictory method is that to make a cloth lighter it must be made *thinner* (supposing that in the first place it is perfectly constructed), and to make it thinner a smaller *diameter* of yarn must be employed; and with a smaller diameter of yarn more threads per inch, in exact proportion to the decreased diameter of the yarn, must be inserted to maintain the balance of structure. Thus the cloth is lighter because more threads and picks per inch indirectly imply a thinner cloth. Similarly, to make a cloth heavier *fewer* threads and picks must be inserted (see Fig. 49, p. 205).

But these statements and facts are put in terms of the diameters of the yarns. To make it practical then—remembering that $\sqrt{}$ counts is in proportion to the diameter—the rule will be—change the $\sqrt{}$ counts of yarns inversely in proportion to the required change in weight, and change the threads per inch in proportion to the required weight change. An example will well illustrate this—

Example.—A cloth is woven of 2/32's cotton, set 60 threads and picks per inch and is required $\frac{1}{4}$ heavier.

$$\tfrac{4}{4} \text{ to become } \tfrac{5}{4}\text{; proportion} = \text{as } 4:5.$$

As $5 : 4 :: \sqrt{16} : \sqrt{x}$ and $x = 10{\cdot}24$ counts of say 2/20's.

As $5 : 4$, or

As $\sqrt{16} : \sqrt{10{\cdot}24} :: 60 : x = 48$ threads and picks per inch.

Proof $$\frac{60 \times 36 \times 1 \times 5}{16 \times 840 \times 4} = \frac{48 \times 36 \times 1}{10{\cdot}24 \times 840}.$$

Another calculation of this type involves a change in weave as well as weight, but as no new principle is involved we refrain from giving it. The varieties of the foregoing calculations are unlimited, but practically all the principles involved have been touched upon; a little common sense and mathematical instinct will lead to a speedy solution of any and all.

The simplification of practical conditions to ensure speedy work may have claim to passing comment.

Example.—A dress cloth when finished contains 88 ends per inch, and 80 picks per inch, is 63 yards long, 48 inches wide, and weighs 14 ounces per yard. It has shrunk 10 per cent. in length, 12 per cent. in width, and lost $\frac{1}{7}$th of its original weight. Ascertain the threads and picks per inch in the loom, length of warp and width of piece as in the loom, weight of material in the grey, and the finished and grey counts of yarn employed.

WARP FINISHED.	WARP IN LOOM.
? Counts of yarn (worsted).	? Counts of yarn.
88 ends per inch.	? Ends per inch.
WEFT FINISHED.	WEFT IN LOOM.
? Counts of yarn.	? Counts of yarn.
80 picks per inch.	? Picks per inch.
Length of warp finished 63 yds.	Length of warp in loom, ?
Width of piece finished, 48 ins.	Width of piece in loom, ?
Weight per yd. finished, 14 oz.	Weight per yd. in loom, ?
$\frac{1}{7}$ loss of original weight.	

To clearly state the problem like this is almost to

answer it. For example, the ounces per yard in the loom stands—

14 oz. + $\frac{1}{7}$ of the original weight = 14 oz. + $\frac{1}{6}$ = 16·33 oz. = per yard in loom.

Again:

As 168 (88 + 80 ends and picks per inch) : 88 :: 14 : x = 7·3 oz. of warp, and $\frac{88 \times 48 \times 1 \times 16}{7{\cdot}3 \times 560} = 16{\cdot}5$'s count (if worsted).

Should the manufacturer be engaged in the Continental or South American trade it may be very desirable that he should work in the Metric System. All the foregoing principles may be readily applied in the Metric System by conversion, or, better still, directly by means of the following particulars:—

Worsted counts	÷	·885	= Metric counts.
Metric counts	×	·885	= Worsted counts.
Cotton counts	÷	·59	= Metric counts.
Metric counts	×	·59	= Cotton counts.
Yorkshire skeins	÷	1·939	= Metric counts.
Metric counts	×	1·939	= Yorkshire skeins.
In dram silk 515	÷	counts	= Metric counts.
515 ÷ Metric counts			= Dram silk counts.

Threads or picks per inch × 3·9 = threads or picks per decimeter.

Threads or picks per decimeter ÷ 3·9 = threads or picks per inch.

Bradford set × 4·33 = threads per decimeter.

Threads per decimeter ÷ 4·33 = Bradford set.

Rule to find the threads per decimeter (*i.e.*, fraction of a decimeter occupied) for any metric counts of yarn:

$\sqrt{\text{Metres per kilogram}} \times 2{\cdot}3$ for woollen yarns.[1]

" " " $\times 2{\cdot}4$ for worsted yarns.

" " " $\times 2{\cdot}5$ for cotton yarns.

Rule to find the threads per decimeter for any ordinary weave:

$$\frac{\text{Diameter of yarn in decimeters} \times \text{Thread in repeat of weave}}{\text{Threads} + \text{Intersections in weave.}}$$
$$= \text{Threads per decimeter.}$$

Example:—Find the threads per decimeter for 2/18's cross-bred yarn employing $\frac{2}{\quad 2}$ twill.

$$\sqrt{9 \times 1{,}000} \times 2{\cdot}4 = 233 \text{ and}$$
$$\frac{233 \times 4}{6} = 155 \text{ threads per decimeter.}$$

Spinning and Weaving Calculations.—In preparing, combing, and spinning, calculations referring to both the machines employed and the materials passing through these machines frequently occur. The mechanical calculations involved cannot be entered into here. Nearly all spinning calculations involve the principle of drivers and driven, and most weaving calculations involve the principles of leverage, but the application of these simple principles are so varied that no satisfactory treatment of them could be given in the space at our disposal.[2]

The calculations referring to weights of slivers in drawing

[1] The slight differences here are allowances for the relative bulkiness of the materials of which the respective yarns are composed.

[2] See the "Wool Year Book," "Woollen and Worsted Spinning," etc.

and spinning, however, should at least claim passing comment. The ultimate end of spinning is, as we have seen, to produce a strand or thread of a certain count, *i.e.*, of a certain number of yards per pound (this is the simplest denomination). Now, working backwards one would expect the slivers always to be stated and calculated in yards per lb., and if it were so there would be many simplifications of drawing and spinning calculations. But in practice it is found more convenient to reel for fairly fine slivers 40 or 80 yards, and for thick slivers 10 yards. Thus English tops are placed on the market 7 ozs. per 10 yards. Botany tops are placed on the market 4 to 5 ozs. per 10 yards. An English top (say 40's quality) is usually made up in a ball about 230 yards long and weighing about 10 lbs. A Botany top (say 60's quality) is usually made up in a ball about 144 yards long, weighing about 5 lbs. Irrespective of these perhaps unnecessary difficulties drafting calculations are comparatively simple, as a sliver loses in weight exactly in proportion to its extension or draft, and necessarily increases in weight in proportion to the doublings. Thus if 40 yards of a "top" weigh 240 drams, then with drafts 5, 6, 8, 8, 6, 9, 9 and doublings 6, 6, 4, 4, 3, 3, 2, 40 yards roving will weigh

$$\frac{240 \times 6 \times 6 \times 4 \times 4 \times 3 \times 3 \times 2}{5 \times 6 \times 8 \times 8 \times 6 \times 9 \times 9} = 2\tfrac{2}{3} \text{ drams.}^{1}$$

In calculating the drafts necessary to give a total draft a difficulty may occur owing to drafts multipling themselves. Consequently if, say, a total draft of 10,368 is required in seven operations, then logarithms or the slide rule must be

[1] See Buckley's "Worsted Overlookers' Hand-book," and "Woollen and Worsted Spinning," by Barker and Priestley.

resorted to, the √ of the total draft being the average draft which may now be varied slightly to suit particular operations. Thus a top weighing 280 drams per 40 yards has to be reduced to 7 drams per 40 yards, at seven operations, the doubling being 6, 6, 4, 4, 3, 3, 2.

280 ÷ 7 = 40 and	log. of 40 =	1·602[1]
	log. of 6 =	0·778
	,, ,, 6 =	0·778
	,, ,, 4 =	0·602
	,, ,, 4 =	0·602
	,, ,, 3 =	0·477
	,, ,, 3 =	0·477
	,, ,, 2 =	0·301
		7)5·617
		·802, log. of.

Answer, = 6·3 draft required.

Another calculation often misunderstood is the following: —To find the number of spindles in any part of the drawing or on the spinning frame, to follow any box of the drawing. If the question involved is simply between two boxes, say *A* and *B*, immediately following one another, then the weight taken by one spindle head on *B* divided into the weight given out by all spindle heads on *A* will be the answer. But should the frames in question be separated by other frames, for example, should the spinning spindles to follow the four-spindle drawing-box be required, then, although the same principle of weight ÷ weight obtains, in addition the relative thickness, or, in other words, lengths of the respective slivers must be taken into account.

Example:—A drawing-box *A* with 4-inch front rollers

[1] Log of draft required if there were no doublings.

making 60 revolutions per minute delivers 240 drams per minute. What number of spinning heads B will be required if the diameter of the back rollers is $1\frac{1}{2}$ inches, making 5 revolutions per minute and taking in 8 drams per minute?

If A delivers the same length that B consumes, then

240 inches = 240 drams per minute from A,

$240 \div 8 = 30$ heads or spindles on box B to follow box A.

But B only takes in $7\frac{1}{2}$ inches relative to A giving out 240 inches, so that

$240 \div 7\frac{1}{2} = 32$ times length of B is required to consume length delivered by A.

Thus the total heads or spindles on B to follow A will be compounded of the weight difference and the length difference—

$$30 \times 32 = 960 \text{ spindles.}$$

It will be evident from the foregoing that many most interesting calculations occur in the textile industries. The points involved in these calculations are ordinary mathematical, geometrical, and trigonometrical principles, and special principles and variations involved by the conditions obtaining in the industry. Many of the calculations could be materially shortened by the adoption of either the standard inch and pound or the metre and the gramme.

The chief point which stands out, however, is the need for some universally intelligible system. If we in this country are not prepared to adopt our own standard of the inch and yard and the pound of 16 ozs., we must be prepared for the metric agitators to prevail—our weakness will be their strength.

CHAPTER XI

THE WOOLLEN INDUSTRY

The Wool Industry may be divided into four main classes, viz., the Woollen Industry, the Worsted Industry, the Stuff or Dress Goods and Lining Industry, and the Upholstery or Tapestry Industry. Each of these has several subdivisions: thus the woollen industry may be considered to include the felt industry, the blanket industry, and in part the hosiery trade; the worsted industry includes also a section of the hosiery trade, and in part the braid trade; while the stuff or dress goods and lining industry includes many varieties almost attaining to distinct classes. The fourth class includes all pile fabrics of an upholstery type, and carpets and tapestry fabrics of a complex character.

The word "woollen" originally referred to fabrics made of the best Continental wool spun on the spindle-draft system, simply woven, felted, and often highly finished. The old "doeskin" was a typical example of the woollen cloth, and the care and skill required for its production may be gauged by the fact that it frequently took six weeks to finish, and sold up to 30*s*. a yard broad width. The present-day army officers' cloths may also be taken as typical of what was understood by the term woollen "in the olden days." It also seems probable that cotton cloths made from yarn spun upon the spindle-draft system and woven

into more or less soft fabrics were sold as woollens. About the year 1813 the re-manufactured materials made their appearance, and very quickly "catching on" became incorporated into the woollen trade, so that to-day the legal definition of a woollen yarn may be taken—as a yarn composed of fibres of any class of materials which may be said to possess two ends, which just possesses the strength necessary to allow the shuttle to lay it in the shed. To-day woollen cloths partake too much of those last named characteristics. Verily our grandfathers would have wept aloud could they have foreseen the degradation which was to overtake their trade and calling. For they were proud of their goods and of their good name for honest dealing. It must not be supposed, however, that the introduction of the re-manufactured materials is entirely a retrograde step. It is surprising what sound goods the Dewsbury and Batley manufacturers can make from low-class raw materials, and we must not forget that thousands of the poorer classes are well clothed by this means who otherwise would have to go very meanly clad indeed. It is the passing of re-manufactured materials as pure wool which must be condemned.

The better class woollen trade is located in the West of England, Huddersfield, Scotland, and Ireland. In the latter country it is not concentrated, but rather distributed.

The medium class woollen trade is largely located in the Leeds district with branches westward into the dales of Yorkshire.

The low class woollen trade is located in the Dewsbury, Batley, and Colne Valley district. The Continental woollen trade is very dispersed. In France, Elbeuf and certain

This press has a tendency to elongate the fabric, but a fine "ironed" surface may be obtained by its use.

In the intermittent form about five yards is treated at once, suitably pressed and held stationary in the heated machine for, say, a minute, and then automatically moved on so that the ensuing section of the fabric may be treated in like manner.

In the continuous form the pressing is continuously effected.

The time factor naturally varies in all three forms, and is naturally the factor which decides which is the most efficient machine for particular classes of goods.

Calendering.—This operation simply consists in passing goods through heavily weighted and if desirable heated rollers which it is found break or render less "caky" fabrics passed through them. The probable action is to distribute rigidity or solidity.

Schreinering.—This operation consists in passing suitably constructed cloths between a pair of solid heavily weighted steel rollers, one of which has a plain papier-mâché surface and the other is ruled with extremely fine lines from 190 to 500 to the inch. The effect on the piece is to develop a really wonderful lustre specially applicable to mercerized cotton goods.

Filling.—As already remarked, it may be desirable or necessary to stiffen some goods to increase their utility. Again, some goods are "filled" simply to attain a desired weight.

Soap or other agents may be cracked in pieces or the pieces may be definitely impregnated with some such agent as chloride of zinc. It is hardly necessary to add again that filling is rarely legitimate.

Conditioning.—After fabrics have passed through a process

involving the application of dry heat—such as singeing—they are unnaturally dry, and as a consequence may be very weak. To give back the natural moisture, goods in such a condition are passed through a machine which "sprays" them and thus causes the fabric to quickly regain the moisture and often the strength lost.

The foregoing are the principal operations in finishing. The secondary operation such as hydro-extracting, burl-dyeing, extracting, etc., are of such minor importance that there is no need to specially refer to them here.

Waterproofing.—Fabrics may be rendered waterproof in three distinct ways. Firstly, the fibres of which they are composed may be rendered moisture-repellent, as, for instance when wool is subjected to the action of superheated steam. Secondly, the fibres may be charged with a water-repellent substance, which thus prevents the passage of water save under pressure. Waxed fibres, for instance, possess this characteristic. Unfortunately oil is hygroscopic, and rather helps the fabric to hold water. In these two cases the surface tension of the liquid which endeavours to pass through the fabric plays an important part. Thirdly, the fabric may be "plastered" or entirely coated with some such agent as india-rubber. Aluminium compounds and waxes are also most successfully employed.

All three methods are employed, and there are, of course, combinations which are not precisely one or the other.

Fireproofing.—Cotton and some artificial silk goods are very inflammable, and it may also be desirable to render other goods less inflammable. The agents employed are such salts as upon a rise in temperature melt and cover the material to be protected.

General Notes.—To give an idea of how the foregoing operations are applied in finishing specific types of fabrics the six following lists are given :—

Woollen Cloth.
(All Wool.)

Perching.
Mending, Burling, etc.
Soaping.
Scouring.
Milling (Stocks).
Milling (Machine).
Washing-off.
Hydro-extracting.
Tentering and Drying.
Brushing and Dewing.
Raising (if required).
Cropping.
Brushing and Steaming.
Cutting.
Dewing.
Pressing.
Steaming-off.
Cold Flatting.
Cuttling.

Worsted Cloth.
(All Wool.)

Perching.
Mending, Burling, etc.
Crabbing.
Soaping.
Scouring.
Mending.
Light Milling.
Washing-off.
Hydro-extracting.
Tentering and Drying.
Brushing and Steaming.
Cropping.
Brushing.
Dry Steam Blowing.
Brushing and Steaming.
Pressing.
Steaming-off.
Cold Flatting.
Cuttling.

Lining Fabric.
(Cotton and Wool.)

Sewing (flat seams).
Winding on to roller prior to Crabbing.
Running on to Crabbing Roller.
Running from Crabbing Roller to Steam Roller.
Steaming.
Drying.
Singeing (about four times).
Souring (wool).
Dyeing (wool).
Dollying.
Throwing.
Rolling on to Steaming. Roller.
Steaming.
Drying.
Singeing (twice).
Dollying.
Hydro-extracting.
Drying.
Tentering.
Press Papering and Pressing.

Silk Fabric.[1]
(Net Silk.)

Singeing or Cropping.
Discharging and Washing.
Drying.
Cylindering.
Damping, or
Dressing and Singeing.
Calendering and Lustring.

Cotton Fabric.[1]
(Calico.)

Singeing.
Souring.
Washing.
Saturating with Caustic Soda.
Kier Boiling.
Washing.
Chemicing.
Washing.

Linen Fabric.[1]
(Standard Style.)

Lime-boiling.
Washing.
Souring.
Washing.
1st Lyre boil.
Washing.
Chemicing.
Washing.
Souring.

[1] These details are supplied by specialists in the respective branches of the industry. All are preceded by operations equivalent to Mending, Burling, etc.

Silk Fabric.[1] (Net Silk.)	Cotton Fabric.[1] (Calico.)	Linen Fabric.[1] (Standard Style.)
Rolling or Plaiting.	Souring.	Washing.
Pressing.	Washing.	2nd Lyre boil.
	Squeezing.	Washing.
	Mangling.	Grassing.
	Drying.	Chemicing.
	Filling.	Washing.
	Drying.	Souring.
	Damping.	Washing.
	Stretching.	Scalding.[2]
	Beetling or Calendering.	Washing.[2]
	Making-up.	Chemicing.[2]
		Washing.[2]
		Souring.[2]
		Washing.[2]
		Scutching.
		Water-mangling.
		Starching and blueing.
		Beetling.
		Breadthening.
		Calendering.
		Lapping.

The foregoing lists seem fairly comprehensive, but in reality they by no means convey a complete idea of the many different styles of finish. For woollen cloths, for example, some half-dozen typical and distinct finishes could be cited, and the other styles are by no means without their varieties (see Fig. 62F).

There can be no doubt but that more attention to the effects of "finish" is much to be desired. To thoroughly demonstrate the influence of each specific process the best method is to pass a suitable length of fabric through the necessary or desirable operations, and to cut off, say, a yard length from the fabric after each operation as a reference. Thus for a piece-dyed Botany coating reference lengths should

[1] These details are supplied by specialists in the respective branches of the industry. All are preceded by operations equivalent to Mending, Burling, etc.

[2] These processes must be varied in accordance with particular requirements.

be preserved of (*a*) warp and weft; (*b*) grey cloth; (*c*) scoured cloth; (*d*) milled cloth; (*e*) dyed and tentered cloth; (*f*) raised cloth; (*g*) cut cloth; (*h*) steamed cloth; and (*i*) pressed cloth. The record of all the foregoing reference samples should include (1) counts of warp and weft; (2) threads and picks per inch; (3) length and width; (4) weight; and (5) strength.

CHAPTER X

TEXTILE CALCULATIONS

In a general sense most textile calculations have, and should have, reference to the ultimate cloth produced. It is true that there is a distinct "wool" trade, a distinct "top" trade, and a distinct "yarn" trade, each of which is in a sense independent of the cloth trade. It is nevertheless obvious that all nomenclature, designation and indication should be on some basis readily understood and easily applied by the cloth constructor.

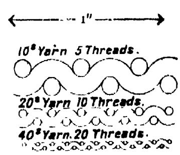


FIG. 58.—Illustrating the Setting of Fabrics; also the Weights of Fabrics.

Unfortunately the "science of cloth construction" was developed so late that not one but many cumbersome methods had long been firmly established, so that to-day a considerable portion of the designer's and cloth-coster's time is wasted on calculations which, with full cognisance of all possible conditions, might easily have been eliminated by the adoption of convenient standard systems for counts of yarn, sets, etc.

Starting from the cloth it is evident that the most useful designation for yarns would be in fractions of the inch (or of a decimeter). Thus 1's yarn would have a diameter of 1 inch, 2's of $\frac{1}{2}$ inch, 3's of $\frac{1}{3}$ inch, 4's of $\frac{1}{4}$ inch, and so on,

or that 1, 2, 3, 4, etc., threads might be laid side by side in an inch. The "set" calculations for cloths on this basis would be very simple. On this basis, as shown in Fig. 49, with plain weave, a 10's yarn would be set five threads per inch, a 20's yarn ten threads per inch, and a 40's yarn twenty threads per inch. Moreover, on this system, the weight of the cloth would vary in inverse proportion to the counts, for, as shown, the cloth with 20's count is half the thickness or weight of the cloth with the 10's count, the cloth with 40's count is half the weight of the cloth with 20's count, and *vice versa*. If the 10's count cloth was a 30 oz. cloth, the 20's count cloth would be a 15 oz. cloth, and so on. Again, the "sets" or threads per inch and picks per inch for any given weave or interlacing would be simplicity itself. As shown in Fig. 59, for example, the threads and picks per inch would be—

$$\frac{\text{Counts of yarn} \times \text{threads in repeat of weave.}}{\text{Threads} + \text{intersections in repeat of weave.}}$$[1]

Thus with a 60's yarn in $\frac{2}{2}$ twill the set should be—

$$\frac{60 \times 4}{6} = 40 \text{ threads and picks per inch.}$$

Of course the practical designer would slightly vary the set in accordance with the material he was using; if rough and slackly twisted he would probably put 38 threads per inch, while if smooth, compact and hard-twisted, he might put 42—44 threads and picks per inch. He would also probably take into account the effects of finish, and, of

[1] This is a fairly accurate approximation for ordinary fabrics in which warp and weft bend equally. Note that it is only applicable in this form if count equals the diameter of the yarn.

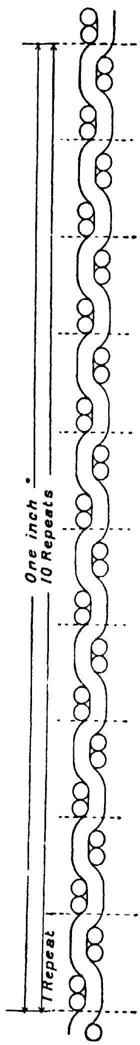


FIG. 59.—Illustrating the Setting of Fabrics.

course, the handle of the ultimate texture he hoped to produce.

Unfortunately this simple system is quite out of count, firstly, because yarn counts designate length and not diameter; and secondly, because yarn and set numbers vary in different localities.

Undoubtedly in the early days of the textile industry yarns were spun very irregularly and to unknown counts in any and every denomination. Then the idea of spinning a definite weight of wool, say, 6 lbs., to a given length of yarn, so that a given length of piece could be got out of it, would impress itself upon the more thoughtful spinners. Thus the Leeds "wartern" is 6 lbs. In Yorkshire "wartern" is derived from a quartern of the old 24-lb. stone, and if the yarn was spun to 1,536 yards, or 1 yard per dram, it was called 1's count, if to 2 yards per dram, 2's count, and so on. In most localities, however, the unit of 1 lb. would be naturally adopted as the weight. Unfortunately there was not the same unanimity with reference to the length. To number 1 yard to 1 lb. 1's count, 2 yards to 1 lb. 2's count, 20 yards to 1 lb. 20's count would be out of the question, as a very thick yarn would then have 256 as its number, and a fine yarn, say, 2,560 as its number. To reduce this count

number to thinkable and workable proportions, in some cases the weight was reduced,[1] and in others the system of "hanking" was resorted to. But the localized character of the various industries unfortunately resulted in a varying weight and a varying number of yards per hank being adopted. In most count systems the hanks per lb. (avoirdupois) indicate the count. Thus 20's count equals 20 hanks per lb., 30's count equals 30 hanks per lb., and so on. But the cotton hank is

LIST XIII.—VARIOUS SYSTEMS OF COUNTING YARNS.[2]

Length variable. Weight constant.

System.	Constant Weight.	Unit Length of Hank.	Yards per hank count, × by gauge point yards per lb
Cotton . .	1 lb.	840 yards	× 1
Worsted . . .	1 lb.	560 yards	× 1
Linen and Hemp .	1 lb.	300 yards	× 1
Raw Silk . .	1 oz.	Number of yards	× 16
Dewsbury .	1 oz.	Number of yards	× 16
Yorkshire Skeins / Woollen . .	6 lbs.	1,536 yards	× ·16
Galashiels . .	24 oz.	300 yards	× ·66
Hawick . . .	26 oz.	300 yards	× ·61
Stirling and Alloa .	24 lbs.	Cuts Yds 48 × 240 (Spindle)	× ·04
West of England .	1 lb.	320 yards	× 1
German wool count .	½ kilog.	2,200 Berlin ells	
Run (American) .	1 oz.	100 yards	× 16
Cut (American) .	1 lb.	300 yards	× 1
Metric . . .	1 kilog.	1,000 metres	× ·45
French Metric . .	½ kilog.	1,000 metres	× ·9

[1] The Yorkshire system may be said to be based upon the yards per dram, and there is also a system based upon yards per ounce, and 1,000 yards per ounce.

[2] See Bradbury's "Calculations in Yarns and Fabrics."

840 yards;[1] the worsted, 560 yards; the linen, 300 yards; Yorkshire woollen skein, 256 yards; West of England, 420 yards; and Galashiels, 300 yards for 24 oz.; so that further complexity has thus been introduced. With the table accompanying, however, the yards per lb. in any denomination may readily be found, and from the yards per lb. any weight or diameter calculation readily worked out.

LIST XIIIA.—VARIOUS SYSTEMS OF COUNTING YARNS.[2]

Length constant. Weight variable.

System.	Constant Length.	Unit of Weight.	Count.
Halifax Rural District	80 yards	1 ram	Repeats of unit weight in unit length = the counts.
Jute, Heavy Flaxes and Hemp	Cuts Yds. 48 × 300 (Spindle)	lb.	
Denier System . .	Raw silk (476 metres or 520 yards)	Denier	
Dram System . .	1,000 yards	Dram	
International Denier .	500 metres	½ decigramme	
Legal Silk count appd. in Paris, 1900	450 metres	½ decigramme	
American Grain .	20 yards	Grain	

Curious to relate, the √ of the yards per lb. of most materials (with a suitable allowance of from 5 to 15 per cent.)

[1] No doubt originating from a reel of a convenient circumference, with a convenient number of warps upon it.

[2] See Bradbury's "Calculations in Yarns and Fabrics."

gives the approximate working diameter of any yarn. Working backwards diameter ^{2} = the area of a square, and the area of a square varies inversely to length; therefore the diameter varies inversely as the $\sqrt{}$ of the length, and as count of yarn is in proportion to length therefore *the diameter of a yarn varies inversely as the $\sqrt{}$ of the counts* (that is denomination being the same).

This accounts for the relationship of diameter of yarn and length or counts, but not for the $\sqrt{}$ of the yards per lb. being the actual numerical diameter in fractions of an inch. This coincidence suggests that there is some method in the madness of the English lb., yard and inch, and that they are not merely haphazard standards. If the metric count system is adopted the $\sqrt{}$ metres per kilogram $\times$ 2·4 = the threads per decimeter; the decimeter being the most convenient unit to adopt for sets.

The most important systems of counting yarns with length constant and weight variable are given in List XIIIA.

In the foregoing particulars the inch is taken as the basis. Unfortunately the inch has been taken as the basis in very few manufacturing districts. The reason for this is not far to seek. Bradford, for instance, apparently based its set particulars upon the yard, Leeds upon the ¼ yard or 9 inches; Blackburn upon 1¼ yards; while possibly other districts, owing to French and Flemish immigration, based their sets upon the Flemish ell or French aune—¾ yards or 27 inches—which later possibly being converted into terms of the yard, would create further confusion.

But this is not all. It was evidently found convenient to

warp with a given number of threads. In Leeds thirty-eight (termed a "porty," no doubt a corruption of the word "portion") were employed; in Bradford forty (termed a "beer"), and so on. Thus it became customary for the set of a fabric to be defined by the number of times the threads warped with repeated in the standard width. Thus the Leeds "set" is the "porties" per quarter (9 inches), the Bradford set the "beers per 36 inches or one yard." So little impregnated with scientific method are the textile industries even to this day that these very local standards are still in full use. Thus the man who speaks of threads per inch in Bradford or Leeds mills speaks in an unknown tongue, and is not in the least understood. Of course there is a tendency to reduce these sets to the threads per inch standard. Thus the Bradford man sometimes states the Bradford set as being based upon $1\frac{1}{9}$ threads per inch; but even he is an exception and usually there is not the slightest endeavour to make the inch the standard; in fact, there is antagonism of a somewhat violent character against any change.

The following are the principal set systems with their gauge points for finding the threads per inch (see List XIV., p. 237).

Some of the most difficult calculations and also some of the easiest possible calculations which the textile designer has to work out have reference to the weight per yard of the fabrics with which he deals. In the worsted coating and the woollen trade the weight per yard (usually 54 inches × 36 inches) is the basis of all dealings; in the stuff, cotton and other trades, although often stated, it is by no means so important. Now under simple conditions of yarns and

set there is no difficulty in calculating the weight of a piece. The calculation simply stands—

$$\frac{\text{Yards of yarn in piece}^{1}}{\text{Yards per lb. of yarn employed}} = \text{lbs. weight of piece,}$$

$$\text{and } \frac{\text{lbs. of cloth} \times 16}{\text{length of cloth in yards}} = \text{oz. per yard.}$$

LIST XIV.—VARIOUS SYSTEMS OF INDICATING THE SET.

Locality and System		Standard width in inches.	Unit Number of Threads in one Beer, Porter, etc.	Given Set to find ends per inch.
Yorkshire	Bradford	36	40	× 1·11
	Leeds	9	38	× 4·22
	Huddersfield and U.S.A.	1	Splits per inch × ends in splits.	
	Dewsbury	90	38	× ·422
Lancashire	Bolton	$24\frac{1}{4}$	40	× 1·64
	Blackburn	45	40	× ·9
	Manchester	36	2	× ·055
	Stockport	2	2	× 1
Scotch	Glasgow	37	2	× ·054
	Tweed	37	40	× 1·08
Belfast and North of Ireland	Linen Plain, etc.	40	2	× ·05
	,, Damask	30	40	× 1·33
	,, ,,	37	2	× ·054
	,, ,,	Ends per inch × reed width.		
	Silk	Width of fabric, number of ends in each split.		

There are, however, a few complications likely to arise. Yarn counts may be in two or more denominations, threads of various counts or thicknesses may be twisted together

[1] This further extended is:

$$\frac{\text{Threads per inch} \times \text{width in loom} \times \text{yards long of warp}}{\text{Warp counts} \times \text{hanks per lb.}} +$$

$$\frac{\text{Picks per inch} \times \text{width in loom} \times \text{yards long of cloth}}{\text{Weft counts} \times \text{hanks per lb.}} = \text{lbs. of cloth,}$$

to form part or the whole of either warp or weft, warp and weft may be composed of several colours, there may be differences in shrinkage and losses in weight of warp and weft during finishing, and other disturbing influences of a less pronounced type. All the foregoing influences, with one exception, are either so easy of comprehension or are necessarily so dependent upon practical conditions that no attempt need be made to deal further with them here. The exception is the twisting together of yarns of varying thicknesses. For instance, what is the "count" of a 40's cotton twisted with a 40's cotton; a 30's cotton twisted with a 40's cotton, and a 30's cotton twisted with a 60's worsted?

There are really four methods of working out such problems as these.

Example and 1st Method.—Base the calculation upon a yard of each material being twisted together.

Thus the first calculation will stand—

$$\frac{1 \text{ lb.}}{40 \times 840} + \frac{1 \text{ lb.}}{40 \times 840} = \frac{1}{16.800} \text{ of } 1 \text{ lb.}; \textit{ i.e.}, 1 \text{ yd.} = \frac{1}{16,800} \text{ of } 1 \text{ lb.} \therefore 1 \text{ lb.} = 16,800 \text{ yards} = \frac{16,800}{840} = 20\text{'s}$$

cotton counts.

Example and 2nd Method.—Work upon the L. C. M. of the number, take this as the length in hanks and proceed as before.

Thus the second calculation will stand—

L. C. M. of 30 and 40 = 120 hanks as length for combination.

$$\frac{120}{\frac{120}{30} + \frac{120}{40}} = \text{hanks per lb.} = \text{counts.}$$

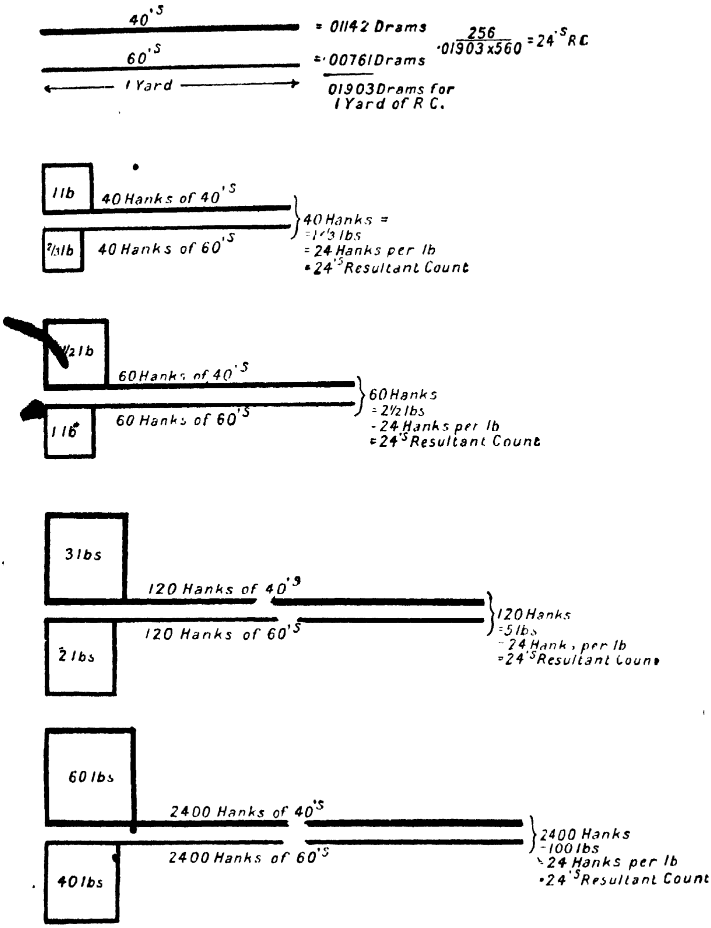


FIG. 60.—Graphic Illustration of the Resultant Counts of Twisting together two Threads of Different Counts.

This is better stated as follows—

Hanks.		lbs.
$120 \div 30$	$=$	4
$120 \div 40$	$=$	3

120 weighing 7 = 17 hanks per lb. or 17's counts.

Example and 3rd Method.—Work by means of the suitable, if somewhat large numbers, found by multiplying the two count numbers together.

Thus the third calculation will stand—

$$(60\text{'s worsted} = \frac{60 \times 2}{3} = 40\text{'s cotton}),$$

$$30 \times 40 = 1{,}200 \text{ hanks.}$$

$$\frac{1{,}200}{\frac{1{,}200}{30} + \frac{1{,}200}{40}} = \text{hanks per lb.} = \text{counts.}$$

The second method seems so much more convenient than the other two that it is most desirable to adopt it whenever possible. Its convenience is all the more marked when the prices of the yarns are given and the price per lb. of the resultant count is required; and again when three or more yarns are to be folded together. Such calculations are so simple in the light of the foregoing that it is not considered necessary to treat them further here (see graphic illustrations, Fig. 60).

The changing of the weights of cloths presents one or two features which are somewhat curious and should be specially noted. For instance, to make cloths lighter—(*a*) Warp may be kept the same, and a thinner weft or fewer picks per inch of the same weft may be inserted; or if the cloth is

built on the square (*b*) the whole structure of the cloth may be changed and *more* threads and picks per inch may be inserted of a finer yarn. The explanation of this seemingly contradictory method is that to make a cloth lighter it must be made *thinner* (supposing that in the first place it is perfectly constructed), and to make it thinner a smaller *diameter* of yarn must be employed; and with a smaller diameter of yarn more threads per inch, in exact proportion to the decreased diameter of the yarn, must be inserted to maintain the balance of structure. Thus the cloth is lighter because more threads and picks per inch indirectly imply a thinner cloth. Similarly, to make a cloth heavier *fewer* threads and picks must be inserted (see Fig. 58, p. 230).

But these statements and facts are put in terms of the diameters of the yarns. To make it practical then—remembering that $\sqrt{}$ counts is in proportion to the diameter—the rule will be—change the $\sqrt{}$ counts of yarns inversely in proportion to the required change in weight, and change the threads per inch inversely in proportion to the required weight change. An example will well illustrate this—

Example.—A cloth is woven of 2/32's cotton, set 60 threads and picks per inch and is required $\frac{1}{4}$ heavier.

$$\tfrac{4}{4} \text{ to become } \tfrac{5}{4}\text{; proportion} = \text{as } 4:5.$$

As $5 : 4 :: \sqrt{16} : \sqrt{x}$ and $x = 10{\cdot}24$ counts of say 2/20's.

As 5 : 4, or

As $\sqrt{16} : \sqrt{10{\cdot}24} :: 60 : x = 48$ threads and picks per inch.

Proof $$\frac{60 \times 36 \times 1 \times 5}{16 \times 840 \times 4} = \frac{48 \times 36 \times 1}{10{\cdot}24 \times 840}.$$

Another calculation of this type involves a change in weave as well as weight, but as no new principle is involved we refrain from giving it. The varieties of the foregoing calculations are unlimited, but practically all the principles involved have been touched upon; a little common sense and mathematical instinct will lead to a speedy solution of any and all.

The simplification of practical conditions to ensure speedy work has claim to passing comment.

Example.—A dress cloth when finished contains 88 ends per inch, and 80 picks per inch, is 63 yards long, 48 inches wide, and weighs 14 ounces per yard. It has shrunk 10 per cent. in length, 12 per cent. in width, and lost $\frac{1}{7}$th of its original weight. Ascertain the threads and picks per inch in the loom, length of warp and width of piece as in the loom, weight of material in the grey, and the finished and grey counts of yarn employed.

WARP FINISHED.	WARP IN LOOM.
? Counts of yarn (worsted).	? Counts of yarn.
88 ends per inch.	? Ends per inch.
WEFT FINISHED.	WEFT IN LOOM.
? Counts of yarn.	? Counts of yarn.
80 picks per inch.	? Picks per inch.
Length of warp finished 63 yds.	Length of warp in loom, ?
Width of piece finished, 48 ins.	Width of piece in loom, ?
Weight per yd. finished, 14 oz.	Weight per yd. in loom, ?
$\frac{1}{7}$ loss of original weight.	

To clearly state the problem like this is almost to

answer it. For example, the ounces per yard in the loom stands—

14 oz. + $\frac{1}{7}$ of the original weight = 14 oz. + $\frac{1}{6}$ = 16·33 oz. = per yard in loom.

Again:

As 168 (88 + 80 ends and picks per inch) : 88 :: 14 : x = 7·3 oz. of warp, and $\frac{88 \times 48 \times 1 \times 16}{7{\cdot}3 \times 560} = 16{\cdot}5$'s count (if worsted).

Should the manufacturer be engaged in the Continental or South American trade it may be very desirable that he should work in the Metric System. All the foregoing principles may be readily applied in the Metric System by conversion, or, better still, directly by means of the following particulars:—

Worsted counts	÷	·885	= Metric counts.
Metric counts	×	·885	= Worsted counts.
Cotton counts	÷	·59	= Metric counts.
Metric counts	×	·59	= Cotton counts.
Yorkshire skeins	÷	1·939	= Metric counts.
Metric counts	×	1·939	= Yorkshire skeins.
In dram silk 515	÷	counts	= Metric counts.
515 ÷ Metric counts			= Dram silk counts.

Threads or picks per inch × 3·9 = threads or picks per decimeter.

Threads or picks per decimeter ÷ 3·9 = threads or picks per inch.

Bradford set × 4·33 = threads per decimeter.

Threads per decimeter ÷ 4·33 = Bradford set.

Rule to find the threads per decimeter (*i.e.*, fraction of a decimeter occupied) for any metric counts of yarn:

$\sqrt{\text{Metres per kilogram}} \times 2{\cdot}3$ for woollen yarns.[1]

„ „ „ $\times 2{\cdot}4$ for worsted yarns.

„ „ „ $\times 2{\cdot}5$ for cotton yarns.

Rule to find the threads per decimeter for any ordinary weave:

$$\frac{\text{Diameter of yarn in decimeters} \times \text{Thread in repeat of weave}}{\text{Threads} + \text{Intersections in weave.}}$$

$$= \text{Threads per decimeter.}$$

Example:—Find the threads per decimeter for 2/18's cross-bred yarn employing $\frac{2}{}\!\!-\!\frac{}{2}$ twill.

$\sqrt{9 \times 1{,}000} \times 2{\cdot}4 = 233$ and

$$\frac{233 \times 4}{6} = 155 \text{ threads per decimeter.}$$

Spinning and Weaving Calculations. In preparing, combing, and spinning, calculations referring to both the machines employed and the materials passing through these machines frequently occur. The mechanical calculations involved cannot be entered into here. Nearly all spinning calculations involve the principle of drivers and driven, and most weaving calculations involve the principles of leverage, but the application of these simple principles are so varied that no satisfactory treatment of them could be given in the space at our disposal.[2]

The calculations referring to weights of slivers in drawing

[1] The slight differences here are allowances for the relative bulkiness of the materials of which the respective yarns are composed.

[2] See the "Wool Year Book," "Woollen and Worsted Spinning," etc.

and spinning, however, should at least claim passing comment. The ultimate end of spinning is, as we have seen, to produce a strand or thread of a certain count, *i.e.*, of a certain number of yards per pound (this is the simplest denomination). Now, working backwards one would expect the slivers always to be stated and calculated in yards per lb., and if it were so there would be many simplifications of drawing and spinning calculations. But in practice it is found more convenient to reel for fairly fine slivers 40 or 80 yards, and for thick slivers 10 yards. Thus English tops are placed on the market 7 ozs. per 10 yards. Botany tops are placed on the market 4 to 5 ozs. per 10 yards. An English top (say 40's quality) is usually made up in a ball about 230 yards long and weighing about 10 lbs. A Botany top (say 60's quality) is usually made up in a ball about 144 yards long, weighing about 5 lbs. Irrespective of these perhaps unnecessary difficulties drafting calculations are comparatively simple, as a sliver loses in weight exactly in proportion to its extension or draft, and necessarily increases in weight in proportion to the doublings. Thus if 40 yards of a "top" weigh 240 drams, then with drafts 5, 6, 8, 8, 6, 9, 9 and doublings 6, 6, 4, 4, 3, 3, 2, 40 yards roving will weigh

$$\frac{240 \times 6 \times 6 \times 4 \times 4 \times 3 \times 3 \times 2}{5 \times 6 \times 8 \times 8 \times 6 \times 9 \times 9} = 2\tfrac{2}{3} \text{ drams.}[1]$$

In calculating the drafts necessary to give a total draft a difficulty may occur owing to drafts multipling themselves. Consequently if, say, a total draft of 10,368 is required in seven operations, then logarithms or the slide rule must be

[1] See Buckley's "Worsted Overlookers' Hand-book," and "Woollen and Worsted Spinning," by Barker.

resorted to, the $\sqrt[7]{}$ of the total draft being the average draft which may now be varied slightly to suit particular operations. Thus a top weighing 280 drams per 40 yards has to be reduced to 7 drams per 40 yards, at seven operations, the doubling being 6, 6, 4, 4, 3, 3, 2.

280 ÷ 7 = 40 and	log. of 40 =	1·602[1]
	log. of 6 =	0·778
	,, ,, 6 =	0·778
	,, ,, 4 =	0·602
	,, ,, 4 =	0·602
	,, ,, 3 =	0·477
	,, ,, 3 =	0·477
	,, ,, 2 =	0·301
		7)5·617
		·802, log. of.

Answer, = 6·3 draft required.

Calculations such as these are comparatively simple, but the problem of deciding drafts and doublings is much more complex, requiring experience and sound judgment. The following are approximations which may prove useful:—

For twistless French drawings:

$$\text{Draft} = \frac{\text{10 to 12 units}}{\text{average fibre length.}^{2}}$$

Doublings = draft — x (a small quantity).

For twisted English drawings:

$$\text{Draft} = \frac{\text{24 to 30 units}}{\text{average fibre length.}^{2}}$$

Doublings = draft — x (a small quantity).

[1] Log of draft required if there were no doublings.

[2] As decided by the Schlumberger Top Testing Machine. Centimetres or inches may be taken as units.

For woollen yarns :

When F = average fibre length, and

K = quality constant, then skeins any material will spin to = $(F \times 20)K$.

For 28's quality	$K = \cdot 4$		For 56's quality	$K = \cdot 9$
,, 32's ,,	$K = \cdot 5$		,, 60's ,,	$K = 1 \cdot 0$
,, 36's ,,	$K = \cdot 6$		,, 64's ,,	$K = 1 \cdot 1$
,, 40's ,,	$K = \cdot 7$		,, 70's ,,	$K = 1 \cdot 2$
,, 50's ,,	$K = \cdot 8$			

Draft which any material will stand :

$$1 + \frac{\sqrt{L}}{2}$$

Drafting twist :

$$\frac{1}{L} \times k$$

In which L = longest fibre in condensed sliver,

k a constant determined by the frictional coefficient of the fibres being spun.

It will be evident from the foregoing that many most interesting calculations occur in the textile industries. The points involved in these calculations are ordinary mathematical, geometrical, and trigonometrical principles, and special principles and variations involved by the conditions obtaining in the industry. Many of the calculations could be materially shortened by the adoption of either the standard inch and pound or the metre and the gramme.

The chief point which stands out, however, is the need for some universally intelligible system. If we in this country are not prepared to adopt our own standard of the inch and yard and the pound of 16 ozs., we must be prepared for the metric agitators to prevail—our weakness will be their strength.

CHAPTER XI

THE WOOLLEN INDUSTRY

THE Wool Industry may be divided into four main classes,[1] viz., the Woollen Industry, the Worsted Industry, the Stuff or Dress Goods and Lining Industry, and the Upholstery or Tapestry Industry. Each of these has several subdivisions: thus the woollen industry may be considered to include the felt industry, the blanket industry, and in part the hosiery trade; the worsted industry includes also a section of the hosiery trade, and in part the braid trade; while the stuff or dress goods and lining industry includes many varieties almost attaining to distinct classes. The fourth class includes all pile fabrics of an upholstery type, and carpets and tapestry fabrics of a complex character.

The word "woollen" originally referred to fabrics made of the best Continental wool spun on the spindle-draft system, simply woven, felted, and often highly finished. The old "doeskin" was a typical example of the woollen cloth, and the care and skill required for its production may be gauged by the fact that this cloth frequently took six weeks to finish, and sold up to 30s. a yard broad width. The present-day army officers' cloths may also be taken as typical of what was understood by the term woollen "in the olden days." It also seems probable that cotton cloths made from yarn spun upon the spindle-draft system and woven

[1] The hosiery or knitting industry is not considered here.

into more or less soft fabrics were sold as woollens. About the year 1813 the re-manufactured materials made their appearance, and very quickly "catching on" became incorporated into the woollen trade, so that to-day the legal definition of a woollen yarn may be taken as—a yarn composed of fibres of any class of materials which may be said to possess two ends, which just possesses the strength necessary to allow the shuttle to lay it in the shed. To-day woollen cloths partake too much of these last named characteristics. Verily our grandfathers would have wept aloud could they have foreseen the degradation which was to overtake their trade and calling. For they were proud of their goods and of their good name for honest dealing. It must not be supposed, however, that the introduction of the re-manufactured materials is entirely a retrograde step: It is surprising what sound goods the Dewsbury and Batley manufacturers can make from low-class raw materials, and it must not be forgotten that thousands of the poorer classes are well clothed by this means who otherwise would have to go very meanly clad indeed. It is the passing of re-manufactured materials as pure wool which must be condemned.

The better class woollen trade is located in the West of England, Huddersfield, Scotland, and Ireland. In the latter country it is not concentrated, but rather distributed.

The medium class woollen trade is largely located in the Leeds district with branches westward into the dales of Yorkshire.

The heavy woollen trade is located in the Dewsbury, Batley, and Colne Valley district. The Continental woollen trade is very dispersed. In France, Elbeuf and certain

small towns like Sedan in the north are the principal centres. In Germany M.-Gladbach, Cottbus, Forst and Werdau are the main centres for cheap goods for men's wear. Verviers, in Belgium, is the centre of a large woollen spinning district, the yarns produced being shipped to England by the ton. In the north of Italy and in Spain woollen and worsted manufacture is developing, while Austria has a textile industry all too little known and appreciated in this country.

The woollen centre in the United States of America is in the New England States, Philadelphia and Boston being the chief cities involved.

The supplies of material for these branches of the woollen trade are derived as follows :—For the fine trade Australian, Cape, South American, and Continental fine wools and some few fine cross-breds and English wools are employed ; for the medium trade coarser Australian, New Zealand, etc., cross-breds with slipe and skin wool, noils, etc. ; and for the heavy trade shoddy, extract, mungo,[1] etc., scribbled with cotton sweepings, etc., to hold the blend together, are largely employed.

The woollen firm is usually self-contained, *i.e.*, it takes in the raw material and delivers the finished cloth, and also often merchants it. There are a few spinners of woollen yarn who do not weave and finish, and the "Rag Grinders" or "Mungo and Shoddy Dealers" of Dewsbury, Batley, and Ossett, form a distinct class to themselves; but these are the exception, not the rule. Thus a woollen mill will, as a rule, include the following machines or sets of machines : –

Scouring Machines.

Drying Machines.

[1] These waste materials average from 200,000,000 to 300,000,000 lbs. per annum.

Willows
Fearnaughts } Placed in the Blending-room.

Conveyors from Blending-room to the Cards.

Scribblers
Intermediates
Condensers } Forming sets of machines to prepare for a given number of spindles.

Mules—pitch and number of spindles to follow cards.

Ring Twisters.

Warping, Dressing, Sizing and Drying Mills, and Machines.

Looms to follow the spinning.

Soaping Machines.

Dollies.

Hydro-Extractor.

Milling Machines.

Stocks.

Crabbing Machines.

Steam-Blowing Machines.

Tentering Machines.

Raising and Brushing Machines.

Cropping Machines.

Presses.

Few mills possess complete sets of scouring bowls—say four or five bowls to the set—as the materials they employ are of such a varied character and comparatively so small in bulk that it pays better to buy bulk lots scoured and to keep a single machine for dealing with the greasy lots. For the same reason the space over the boilers is usually plated as a drying house, although of course the best firms employ drying machines of an approved type, which yield the wool up in a nicely open and dried condition.

The willow is a very rough strong kind of card, which practically tears up and dusts the material, a fan and chimney being connected with it. The fearnaught is a nearer approach to the card, still more finely working the wool and ejecting it as a rule by means of an air blast.[1]

Materials to be blended together are first passed through these machines, then built into a stack, layer by layer, and oiled at the same time, then beaten down with sticks[1] and again passed through the fearnaught. The blend is then allowed to mellow before being passed on to the carding-room. The scribbler card to which the material is subjected opens it out lightly, the intermediate card treats it more severely, while the condensing card ensures a regular film of wool and then divides this film up into a number—say 120 films in 72 inches—of small slivers—count according to count to be ultimately spun to—which are wound on to the condensing bobbin ready for being passed on to the mule. On the mule these condensed slivers are at one operation drafted out to the counts required and twisted, or, if this would be too severe, they are first roved and then finally spun to the required counts. The following particulars respecting the relationships of the cards and mule spindles are useful and interesting (see p. 253).

The operation following spinning and twisting is warping if the yarn is intended for warp. If the yarn is intended for weft it will have been spun directly on to spools fitting the power-loom shuttles; if for warp, on to cops holding a large quantity, and, if possible, a definite length of yarn to avoid waste in "bits." Warping is best effected on the Scotch warping mill, although the cheese system has by no means fallen into disuse. Upon whatever system the warp

[1] Care must be taken that neither air blasts nor sticks sort out long material from short; perfect mixing being the desideratum.

SETS OF WOOLLEN MACHINERY FOR—

Coarse Work.	*Fine Work.*
Scouring.	Scouring.
Drying	Drying
(Carbonizing).	(Carbonizing).
1 Willow.	1 Willow.
1 Fearnaught.	1 Fearnaught.
Blending Process :—	Blending Process :—
1 treble scribbler—breast and 3 swift, Scotch intermediate feed.	1 double scribbler—breast and 2 swifts.
1 double carding engine—breast and 2 swifts, double-doffer condenser.	1 intermediate breast and 1 swift, creel intermediate feed.
1 mule of 400 spindles.	1 double carding engine—breast and 2 swifts, tape condenser.
1 ring-twisting frame of 100 spindles.	2 mules, 600 spindles each.
	1 ring-twisting frame of 200 spindles.
(Yielding, say, 60 lbs. per hour.)	(Yielding, say, 10 lbs. per hour.)

is made a regular tension should be placed upon all the threads; if of a coloured pattern, they must be in their correct order; the right length should be accurately obtained, and the correct width for dressing on to the loom beam. Sizing follows, the idea here being to add a certain amount of strength to the yarn and to glue down the strong fibres and so ensure clear weaving conditions. Drawing-in or twisting follow, and then the warp is mounted in the loom. The favourite loom among woollen manufacturers now is the Dobcross, running at from 80 to 105 picks per minute. Several other firms also make woollen looms of an approved description. It is here interesting to note that in the woollen loom speed does not necessarily mean production, for woollen warps are frequently so tender that running at 80 picks per minute produces more cloth than running at 105 picks per minute. Of course for the cotton warps largely used in the low woollen and flannel trades

much quicker looms may be employed, 110 to 120 picks per minute being frequently attained.

As the woollen fabric leaves the loom it is unsightly, rough, and uncouth. But finishing changes all this. Scouring clears off the size and oil, and, if skilfully done, also clears and develops the colours. Milling bursts the thread and gives a full-looking texture; tentering levels the piece, taking out all creases; crabbing fixes and gives lustre to the piece; raising brings a pile on to the surface; cropping levels it; steaming fixes; and wet-raising, boiling, etc., give a finely-developed permanent lustre.

The following example illustrates how all the processes in woollen manufacture must be applied with a definite idea of attaining a particular type of finished fabric:—A Melton cloth is required in which the finished fabric shows little or no trace of threadiness, but is of a felt-like appearance. To begin with, a good, fairly short, felting wool is required; this should be worked with as little drafting as possible, *i.e.*, condensed fine and spun without roving. The warp and weft yarns should be spun with inverse amounts of twist-in and in the same direction, say, open-band. The twill of the weave, should a twill be employed, should run with the twine of the yarn, so that warp and weft "bed" into one another as much as possible. The fabric must not be too closely set, as the fibres must be given room to take a "finish." The thread structure must be cleared in the scouring, broken in the stocks, and consolidated in the milling machine. The surface fibres must be raised up by dry-raising and closely cropped off to leave a bare clear surface without pile. Should stiffening be necessary, this may be effected by washing off the soaped

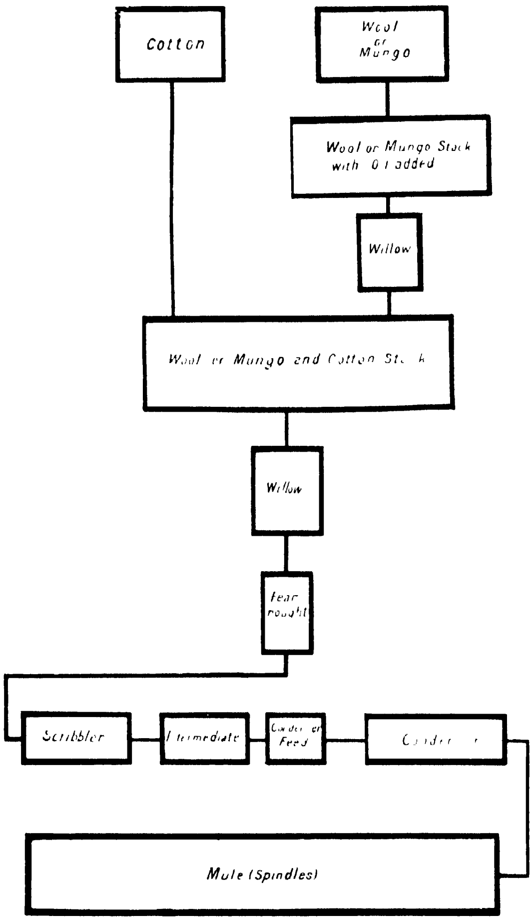


FIG. 61.—Graphic Illustration of the Order of Processes in Woollen Manufacture.

piece with hard water or by adding the necessary stiffening agents. Needless to say, the better piece will be that which requires no stiffening agent. Should the fabric come out of the press too highly glazed, it should be re-steamed to give it the requisite clear but somewhat opaque Melton finish.

Every distinct style of woollen fabric requires special attention in the finishing, as it is the finishing operations which make or mar the piece. A worsted cloth is largely made in the loom, but a woollen cloth is really made in the finishing.

Woollen manufacturers largely merchant their own goods, as distinct from the stuff manufacturers, for example, who cater for the wholesale merchant houses. This is perhaps due to the fact that the woollen trade is largely a home trade, the manufacturing of woollen cloths—no doubt owing to its comparative simplicity—being spread over the world. Japan, for instance, already spins, weaves, and finishes woollens, but buys largely worsted tops and yarns.

In Fig. 61 the relationships of the various processes in woollen manufacturing, one to the other, are shown.

CHAPTER XII

THE WORSTED INDUSTRY

The worsted industry may be said to have risen with the growth and introduction of colonial wools into England. It may be true that its very name carries us back to an industry located in the village of Worsted, in Norfolk, but it is more than probable that did we enquire into this primitive industry we should find that it was principally based upon the production of fabrics which here will be treated under the heading of "Stuffs."[1] For our present purpose, however, it will be convenient to include in this chapter all combed wool yarns and fabrics made entirely of such yarns, along with possibly a few exceptions of the fabrics made of, say, worsted warp and woollen weft. If this is the division adopted, then it is necessary to point out that there are really two distinct branches of the industry—with, of course, many grades in between. Long wools (mostly English) have been combed and made into what are still known to our women-folk as worsted yarns from time immemorial. St. Blaize, a bishop of the fourth century, was the patron saint of the wool-combers, and for how long the industry had been established before his time it is difficult to say. We are fairly safe in assuming that prior to about 1830 worsted or combed yarns were made from

[1] See Chapter XIII.

long wool of a somewhat coarse and harsh character, and that the modern "Botany yarn" was almost unknown. Prior to 1830 fine Continental wools would no doubt be placed on the market as hosiery yarns, but they would be spun on the woollen principle, and were no doubt synonymous with what are to-day termed "merino" yarns. From 1830 onwards the longer colonial merino wools were combed by hand, and about 1840 Lister (Lord Masham) first attempted the combing of short English wools (Southdown), and later of colonial wools, by mechanical means. Prior to this, attempts had been made to comb wool mechanically, but inventors were more concerned with the production of any mechanism which would comb wool, so that we are fairly safe in assuming that the combing attempted was with long wool. Curious to relate, Lister soon abandoned his attempt to comb short wool, becoming more interested in his "nip" comb, which was more suited to the long varieties of wool, leaving the field clear for the Holdens so far as this country was concerned, and Heilmann and the Holdens so far as the Continent was concerned. Thus, from 1850 onwards there has been a steady advance in the capabilities of the machine comb, until to-day the Heilmann and Noble combs will comb wools of, say, 2 inches, which even a few years ago would have been put on one side as being only suitable for clothing purposes. The genesis of the wool comb is illustrated graphically in List I. Every stage therein forms a romance of industry.

It was about the year 1879 that the fine woollen trade was "hit" by the introduction of fine wool "worsteds." Woollen manufacturers, who a few years previously had reckoned their profits in thousands or tens of thousands, either had to change on to the new style of machinery or

had to close down. The fine black cloth– the standard clothing of the middle and upper classes– became almost a thing of the past. Thus it came about that the worsted industry, instead of being almost wholly concerned in the rougher sorts of wools, became more and more concerned in the finer wools, so that to-day it is impossible to say whether the prepared, combed, and drawn long wool yarns or the carded, combed, and drawn short wool yarns form the bulk of the trade. But during the past ten years, again owing to the large supply of a suitable medium wool —neither long nor short—what is known as the cross-bred trade has arisen. Cross-bred wools are usually carded, combed, and drawn, but the yarns produced cannot be compared to Botany yarns for softness and delicacy. To-day, owing to the tendency to produce a big carcass sheep, these wools form the bulk sorts of New Zealand and the coastal districts of Australia and South America, and the yarn and cloth trade in these wools is proportionately large.

The worsted "top and yarn" trade is located in Bradford and district, but some few and not unimportant firms are outside this district. Worsted yarns of the fine, cross-bred and long wool type are woven, dyed, and finished in various parts of the country, each district, as it were, making a speciality of a certain style. Thus Huddersfield leads the world in the finest worsteds for men's wear; Bradford and Halifax are pre-eminent for the cheap production of plain style worsteds for both men's and women's wear; and Scotland now consumes large quantities of cross-bred and Botany yarns, which are made into Scotch tweeds and other fancy worsted styles, mostly for men's wear. The corresponding Continental centres are Elbeuf and Aachen. Of

course, the correspondence is not exact. Thus, while Elberfeld makes linings similar to Bradford, no combing and spinning of moment is to be found there, and so on. Philadelphia, Boston and Jamestown are the corresponding United States centres.

The worsted trade, as distinct from the woollen trade, is organized into several distinct divisions. It is true that in certain parts of the country there are firms who buy wool direct, or at the London sales, scour, comb, spin, weave, and finish it. But these firms are the exceptions, the trade as a whole being organized as follows:—

1. **The Wool Buyers.**—This branch of the trade originally bought the wool from up and down the country or in London and resold it to the combers. Of late years, however, there has been a tendency to combine this trade with the combing.

2. **The Combers.**—This branch takes the raw material, scours it, prepares or cards, combs it, and places it on the market in the "top" form.

3. **The Spinners.**—This branch deals with the "tops" as delivered from the combers, converting them by means of drawing and spinning processes into yarns.

4. **The Warpers and Sizers.**—This branch deals with the warping and sizing of the spinning yarns prior to weaving. Thus, warpers and sizers frequently keep standard qualities of their spinners' yarns, and warp, size, and dress on to the manufacturers' loom beam to order.

5. **The Manufacturers.**—This branch weaves into the required fabrics the yarns, etc., supplied by the spinner or the warper and sizer.

6. **The Dyers and Finishers.**—This branch, now largely

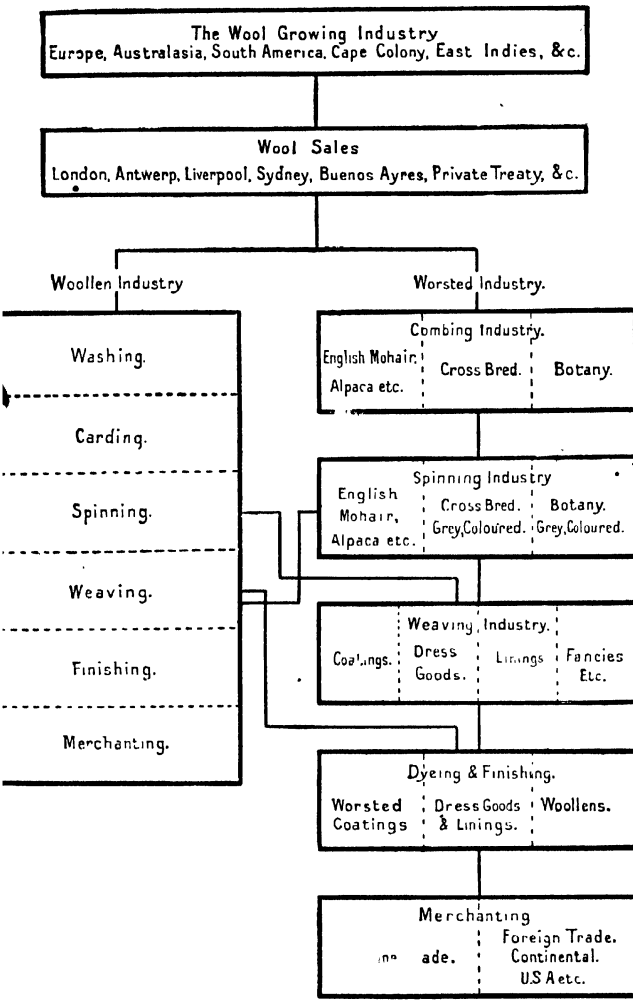


FIG. 62A.—Graphic Illustration of Woollen and Worsted Industries.

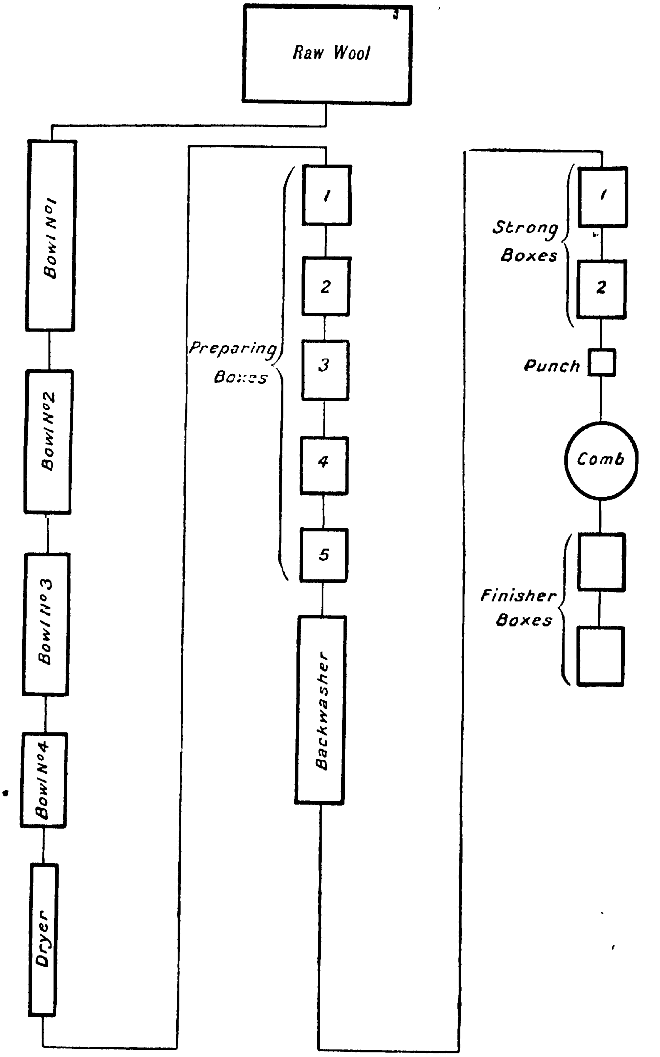


FIG. 62B. - Graphic Illustration of Combing Processes for Long Wool.

organized as a combination under the title of the Bradford Dyers' Association,[1] scours, dyes, and finishes the immense variety of goods forwarded to its various branch works, each of these latter being specialized to deal with particular styles of goods.

7. The Merchants.—The large wholesale houses in Bradford at one time almost controlled—and certainly developed—the Bradford trade. To-day there is manifested a tendency for manufacturing concerns to merchant their own goods, but notwithstanding this the merchanting trade of Bradford is in a very healthy condition.

There are several minor branches of the trade in addition to the foregoing main divisions. Thus there are comb-makers, spindle-makers, loom-makers, and the designers and card-cutters.

SETS OF MACHINES FROM WOOL TO THE YARN.

Botany.	*English.*
1 Willow.	1 Willow.
1 Four or Five-bowl Scouring Set.	1 Three or four-bowl Scouring Set.
10 Cards.	1 Dryer.
2 Backwashers.	1 Set of six Preparing-boxes.
2 Sets of two Strong boxes.	6 Nip Combs.
1 Punch.	3 Sets of two finishers.
8 Noble Combs.	(Backwashing to be added if required.)
5 Sets of two finishers.	
	About six Sets of English Drawing will be required to follow this.

[1] A few not unimportant dyeing and finishing firms are not in this combine.

Botany (contd.).

Top Dyeing Plant.

2 Twenty-eight Can Top Dye-Machines.
1 Backwasher.
2 Mixing Boxes.

Re-combing Plant.

2 Winders.
3 Sets of two Breaking-up Boxes.
1 Punch.
4 Noble Combs.
2 Sets of two finishers.

Drawing Plant.

3 Sets of Botany Drawing Machinery, and
1 Set of French Drawing Machinery.

It is not possible to give details of all the machinery employed in the industry, but the above indicated sets of machinery for English cross-bred and Botany yarn production, in conjunction with the information given in previous chapters on preparing, spinning, etc., will enable a comprehensive grasp of the subject to be obtained.

In the worsted and woollen industries the type of work is so miscellaneous that weaving machinery is rarely supplied in sets. In the cotton industry, however, sets are most carefully calculated for specific types of fabrics.

Worsted looms may be run much quicker than woollen looms, an additional speed of at least 20 per cent. often being possible. As a rule, a greater shedding or boxing, or both shedding and boxing, capacity, is required in the worsted loom as compared with the woollen loom, as worsted goods are made in the loom, and not in the finishing, as are woollen goods. Extreme fancy woollens, however, are as difficult and complex in the making as fancy worsteds.

The fabrics produced in the worsted trade may usually be classed under the heading of Botanies, Crofs-breds, or English. The plainer styles in all qualities are woven in

$\frac{2}{2}$, $\frac{3}{3}$, $\frac{4}{4}$ twills and other standard weaves. For women's wear, when fashion is favourable, large numbers of jacquard figured styles are produced, while for men's wear backed and double cloths and very complex schemes of interlacing and colouring are regularly to be met with. Special note should be made of the colouring, as the organization of the Botany coloured yarn trade of Bradford and Huddersfield is unequalled elsewhere in the world, unless it be in the Lyons silk trade.

The finishing of worsted goods has been defined in the chapter on "Finishing." Note should be made, however, of the fact that there are to-day many "worsted finishes." Time was when worsted coatings invariably wore "greasy." Such is not the case to-day—at least, not if the finisher has done his work well. Again, worsteds may be produced soft or crisp at will by maintaining satisfactory conditions. Thus, just as in the case of the woollen cloth, the final product is decided by the primary selection of the raw material, by the way in which that material is prepared and spun, by the way in which the fabric is constructed and woven, and finally by the finishing. It is not one but all these factors which must be considered carefully if characteristic worsted cloths are to be produced.

The merchanting branch of the trade may be conveniently divided into the "home trade" and the "shipping trade." Owing to this division and to the variety of textiles produced, it is questionable whether Bradford should be considered a city of one trade. It is further questionable whether the total trade fluctuation is greater than in a city of recognized diversified trades, such as is Leeds.

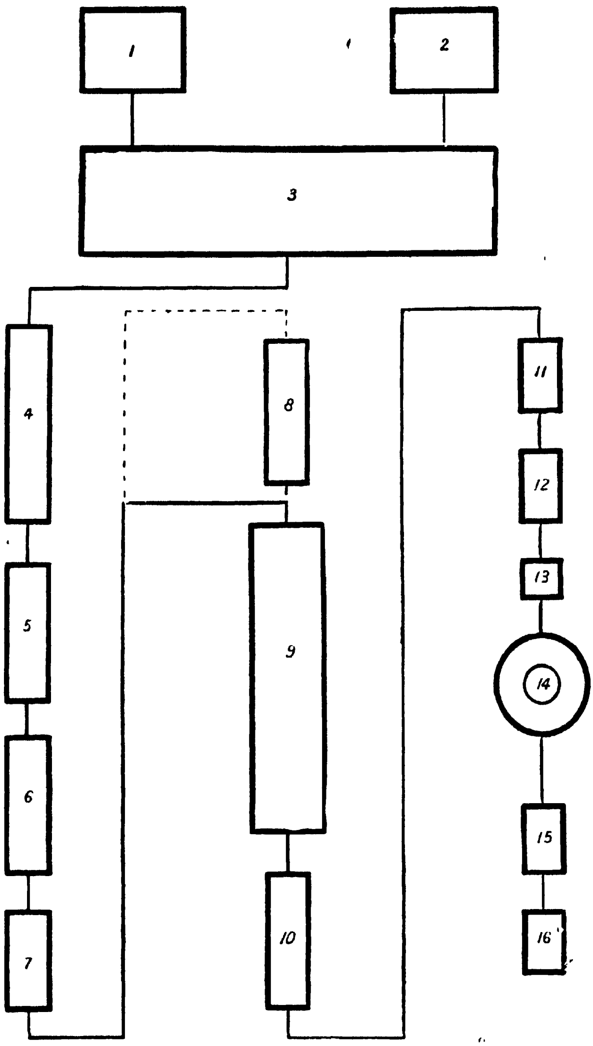


FIG. 62c – Graphic Illustration of the Combing Processes for Short Wool 1 and 2, wools to be treated; 3, blend of wools (1) and (2); 4, 5, 6 and 7, washing bowls; 8, dryer (not always used); 9, carder. 10, backwasher; 11 and 12, strong boxes; 13, punch for balling slivers for comb; 14, Noble comb; 15, 1st finisher; 16, 2nd finisher. *Note.*—The balance of machines is not here preserved; thus one set of scouring would keep perhaps twelve combs running (see p. 238).

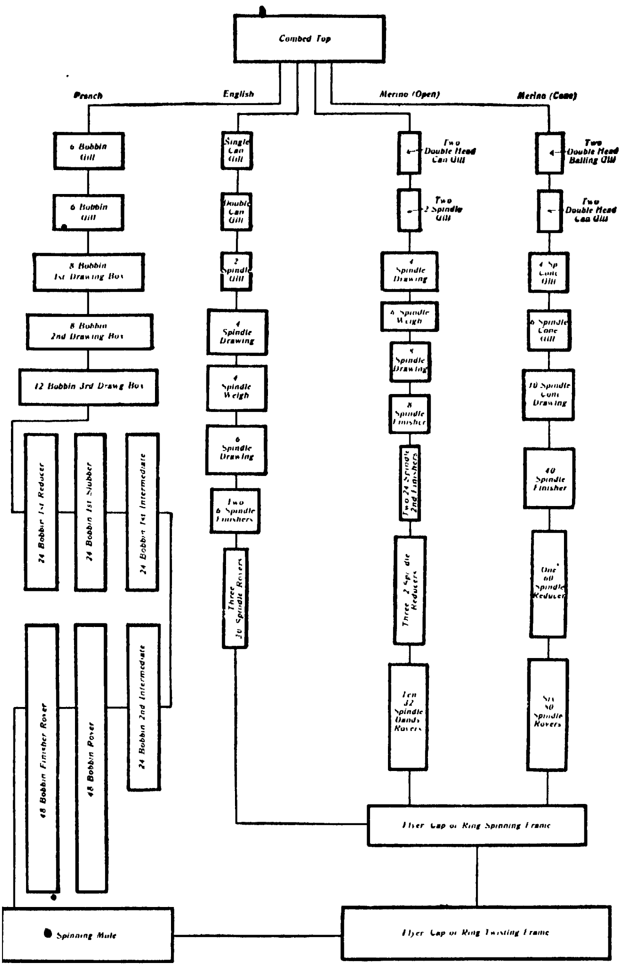


FIG. 62D.—Graphic Illustration of the Drawing and Spinning Processes on the French, English, Merino (Open), and Merino (Cone) Systems.

The following tables, taken from the Bradford Chamber of Commerce's "Statistics of the Worsted and Woollen Trades," convey useful information respecting the "top," yarn, cloth, and dress-stuff trades.

List XIV.—Exports of Wool-Waste, Noils, and Tops.

Year.	Total	
	lbs	£
1908	55,203,200	3,532,153
1909	66,695,400	4,342,835
1910	71,269,200	5,170,397
1911	67,658,400	4,766,852
1912	76,553,000	5,352,811
1913	77,519,300	5,831,569
1914	61,775,800	4,865,884
1915	35,598,000	3,365,435
1916	43,838,400	5,178,949
1917	32,201,900	4,765,070
1918	23,375,700	4,634,705
1919	34,420,500	7,163,617

List XV.—Exports of Combed or Carded Wool and Tops.

	1913.		1914.		1915.		1916.	
	Quantities	Value.	Quantities	Value.	Quantities	Value.	Quantities	Valu
To.	lbs.	£	lbs	£	lbs.	£	lbs	£
Russia .	1,176,300	103,903	1,045,200	92,782	261,800	34,385	182,500	29,7
Sweden .	5,333,000	435,954	4,128,800	349,276	986,700	101,551	2,086,700	257,4
Norway .	585,400	44,400	460,000	37,002	321,200	34,523	550,200	66,0
Denmark	469,700	34,130	449,400	33,642	463,000	50,601	489,600	59,1
Germany	16,234,600	1,260,308	11,426,000	894,114			-	---
Holland	3,571,500	272,504	2,916,300	225,893	1,363,900	126,818	1,920,400	211,3
Belgium	2,378,400	176,102	1,876,700	140,685	-	—		—
France .	1,108,100	95,039	604,800	54,474	3,559,400	465,115	7,861,200	1,413,5
Portugal	273,100	28,058	269,800	28,761	414,400	53,162	161,300	22,4
Spain .	933,000	84,593	649,600	61,913	345,900	35,070	78,400	11,5
Italy .	2,046,100	162,527	1,509,200	124,531	2,066,700	236,141	3,949,700	530,8
Austria-Hungary	610,000	47,879	223,100	16,838		-		—
Japan .	5,147,000	618,262	3,708,100	451,948	854,300	113,114	278,200	46,8
Other Foreign Countries	687,900	62,594	5,519,700	498,280	1,707,200	135,098	567,500	56,8
Canada .	3,078,100	225,546	2,008,300	150,625	3,834,100	398,252	1,330,900	530,3
Other British Possessions	—	- -	45,300	3,072	22,300	2,320	98,000	16,0
TOTAL	43,633,100	3,651,799	36,840,300	3,163,836	16,200,900	1,786,150	22,554,600	3,253,5

List XV.—Exports of Combed or Carded Wool and Tops *continued.*

	1917.		1918.		1919	
	Quantities	Value.	Quantities	Value	Quantities	Value.
	lbs	£	lbs	£	lbs	£
To: –						
Russia .	257,900	37,642	-		-	
Sweden .	21,200	2,763			1,849,800	285,785
Norway .	128,500	18,280				-
Denmark .	158,100	21,573	-		-	-
Germany .	—		—		-	
Holland .	278,800	37,610	-	-		—
Belgium .		-		-	-	- -
France .	4,136,000	975,588	2,835,300	879,582		-
Portugal .	56,700	10,538	10,200	2,000		-
Spain . .	92,600	14,080				-
Italy . .	5,262,500	889,706	6,768,400	1,343,906	- -	-
Austria-Hungary		—	-	-		
Japan .	1,000	232	-		10,400	3,804
Other Foreign Countries	148,900	23,789	6,100	1,085	-	-
Canada .	3,789,800	590,224	5,434,900	1,003,500	—	-
Other British Possessions.	11,800	6,131	5,700	898	-	
Total .	14,373,800	2,628,156	15,060,600	3,230,971	14,866,000	3,220,298

List XVI.—Woollen and Worsted Yarns.

Year	Imports.		Exports	
	Weight in lbs	Value in £.	Weight in lbs	Value in £
1909	23,985,703	2,441,018	81,315,600	7,177,825
1910	27,546,472	2,795,574	94,253,900	9,046,394
1911	27,497,777	2,852,308	91,081,100	8,919,688
1912	30,586,909	3,171,657	87,888,900	8,225,567
1913	32,993,997	3,532,656	80,415,300	8,040,415
1914	18,588,525	2,065,610	53,413,400	5,541,967
1915	653,811	81,849	21,724,200	3,189,966
1916	428,010	60,765	33,090,700	6,444,240
1917	113,649	18,486	23,752,300	5,660,326
1918	15,036	3,268	16,377,900	6,392,365
1919	•2,826,705	1,036,504	32,230,100	12,964,205

List XVII.—Manufactures of Wool.

Year.	Imports.	Exports.[1]
	Value in £	Value in £.
1909	6,148,004	34,768,443
1910	5,653,321	42,659,823
1911	5,637,583	42,652,968
1912	5,802,692	43,819,362
1913	5,772,801	44,241,611
1914	4,506,852	37,127,548
1915	1,333,622	37,267,139
1916	495,039	52,356,399
1917	39,191	58,292,401
1918	111,406	54,593,161

[1] In this column flocks, shoddy, wools, and waste are included.

List XVIII.—Imports of Wool Dress-stuffs, Flannels and Delaines.

	1913.		1914.		1915.		1916.	
	Quantities	Values	Quantities	Values.	Quantities.	Values	Quantities	Values.
	Yards	£	Yards.	£	Yards	£	Yards.	£
From .								
France .	43,037,990	3,492,979	35,234,824	3,014,586	1,914,635	168,325	712,820	77,358
Germany .	13,370,424	1,063,733	7,897,002	677,734	4,558	553	3,800	355
Holland	202,420	23,097	217,220	21,331	371,380	37,029	12,563	2,067
Belgium .	1,029,198	103,886	911,491	91,709	126,991	10,264		-
Switzerland	1,287,351	64,476	824,082	49,553	1,879,211	117,078	475,495	31,855
Austria-Hungary .	113,077	10,016	50,905	5,528	–		– –	– –
Other Countries	46,403	2,845	46,947	5,184	1,019,908	79,182	891,086	52,722
	59,086,863	4,761,032	45,182,561	3,855,625	5,316,683	412,231	2,098,764	164,357
Less Re-exports .	7,831,673	592,535	7,995,019	622,639	1,217,588	98,960	1,116,715	93,050
Net Imports	51,255,190	4,168,497	37,187,542	3,232,986	4,099,095	313,471	982,049	71,307

List XVIII. Imports of Wool Dress-stuffs, Flannels, Delaines *continued.*

	1917.		1918.		1919.	
	Quantities	Values.	Quantities	Values	Quantities.	Values.
	Yards	£	Yards	£	Yards	£
From –						
France .	318,323	31,466	242,922	27,088	1,013,652	270,493
Germany . .	—	–		–	–	–
Holland . .	—	–		–	—	–
Belgium .	– –	–		–	—	–
Switzerland .	– –			–	– –	—
Austria-Hungary		Japan	260,927	21,914	–	– –
Other Countries .	32,095	2,116	1,346	167	—	– –
	350,418	33,582	505,195	49,169	1,645,642	317,574
Less Re-exports	201,475	26,457	22,136	3,821	93,008	25,092
Net Imports .	148,943	7,125	472,959	45,348	1,552,634	292,482

List XIX. Imports of Wool Cloths.

	1913		1914.		1915.		1916.	
	Quantities.	Values	Quantities.	Values	Quantities	Values.	Quantities	Values.
	Yards	£	Yards.	£	Yards	£	Yards	£
From –								
Germany .	1,092,312	164,035	1,136,990	165,767	–		–	– –
Holland .	480,709	59,180	969,658	103,401	1,460,255	134,968	78,067	8,129
Belgium .	366,577	70,058	195,759	34,074	1,000	500		—
France .	672,856	123,105	558,991	106,281	70,669	12,012	104,534	19,819
Austria-Hungary	17,372	2,898	852,779	129,616	865,171	134,680	– – –	–
Other Countries .	147,552	19,661					166,224	25,024
	2,777,378	439,237	3,714,180	539,142	2,400,095	282,160	348,825	52,972
Less Re-exports .	280,369	54,643	494,394	81,742	167,411	30,423	61,158	12,601
Net Imports	2,497,009	384,594	3,219,786	457,400	2,232,684	251,737	287,667	40,371

LIST XIX.—IMPORTS OF WOOL CLOTHS—*continued.*

	1917.		1918.		1919.	
	Quantities.	Values.	Quantities.	Values.	Quantities.	Values.
	Yards.	£	Yards.	£	Yards.	£
From :—						
Germany . .	3,610	889	—	—	—	—
Holland . .		—	—		—	—
Belgium .	—	—	—		—	—
France	103,704	28,878	71,330	30,567	—	—
Austria-Hungary	—	—	—	—	—	—
Other Countries .	19,377	5,683	342	88	—	—
	126,721	35,450	71,672	30,655	225,662	105,668
Less Re-exports	14,213	4,562	4,113	2,037	20,478	17,274
Net Imports	112,508	30,888	67,559	28,618	205,184	88,394

CHAPTER XIII

THE DRESS GOODS, STUFF, AND LININGS INDUSTRY

It is probable that from the earliest days dress goods and fabrics generally destined for women's wear have been very diversified in material, texture, and design. Tapestries might be more elaborate in design and richer in texture, but certainly not so varied in style. It is probable that for centuries wool textures have occupied a leading position for women's ordinary wear. Coarse woollens of the "winsey" type were no doubt manufactured in bulk for the lower classes; somewhat finer fabrics of the serge type would be the bulk sorts for the better classes along with cashmeres; while the upper classes would more largely patronize silks. Linen was of course largely used as an under-wear, and it is more than probable that, prior to the introduction of the cotton frock, linen fabrics would be used for a similar purpose. Our Eastern trade, dating from the seventeenth century resulted in the introduction of fine cotton goods in the shape of muslins, etc.; but it was quite late in the day before we were able to manufacture these and produce somewhat similar styles in wool under the name of "mousseline-de-laine." It is thus quite easy to understand how the Dress Goods trade of to-day has come to be so comprehensive in its employment of nearly

every textile fibre and every possible combination of the same.

Prior to about 1837 all wool (woollen or worsted), all silk, all linen, and some few wool, silk, and linen combinations, were the standard styles. With the introduction of cotton warps about this time and the extended use of cotton about 1856 the possibilities of the combination of various materials was more fully realized, resulting in what is known as the "Stuff Trade." Thus cashmere cloths, which, prior to this period, had been made from wool warp and wool weft, were made with cotton warp and wool weft; the Italian cloth, again a cotton warp and wool weft style, was introduced or re-developed; the use of mohair in conjunction with cotton was exploited, resulting in the discovery of a whole range of fabrics variously spoken of as Sicilians, Brilliantines, Orleans, etc.; and a little later Sir Titus Salt placed his far-famed Alpaca styles upon the market. Thirty years later, and the mercerizing of cotton again upset the commercial equilibrium of Bradford. Mercerized goods in a pure form have partially taken the place of the ordinary botany weft Italian, and in their varieties in the shape of lustred (Schreinered) goods and blistered or crepon styles have made a lasting impression upon the fancy dress goods trade.

Largely owing to being first in the field, and to very successful spinning, Bradford has well maintained its lead in such dress goods as involve the employment of English wools, mohair, alpaca, etc., these being termed hard goods as distinct from the soft Botany styles. With these latter styles the French always seem to have been the most successful, simply because of the style of combing and spinning adopted, Bradford early adopted the Danforth spindle or cap frame,

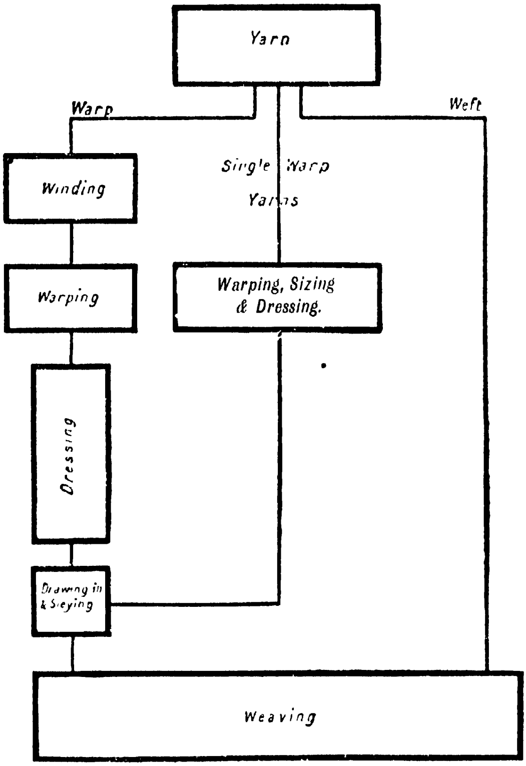


FIG. 62E.—Warping, Sizing, Dressing, etc., Processes.

a spinning machine admirably adapted for the production of bad, solid Botany yarns[1] typically suited to the Italian

[1] Roughness must not be mistaken for fulness. The cap frame can only be considered to spin a "full" yarn in comparison with the flyer frame.

and worsted coating trades. France placed its faith in the mule, and by the time of the Great Exhibition in 1851[1] had already made a name for soft mule-spun fabrics. From that time to the present, notwithstanding both public and private endeavours, France has well held her own. True it is that when fashion favoured the hard stuffs of Bradford, Roubaix seriously discussed the possibility and advisability of adopting Bradford's method of spinning; but upon the whole they have lost nothing by keeping to the mule. Within the last two years Yorkshire has again seriously considered the advisability of producing more mule-spun yarns, the Chamber of Commerce taking a strong lead in the deliberations held, and several firms have now successfully overcome the difficulties, both practical and economical, and are placing on the market mule-spun worsted yarns as satisfactory and as cheap as the French yarns. In such goods as Amazons these mule-spun yarns are employed as warp with a woollen yarn as weft. This woollen yarn, of which tons are used in Yorkshire and Scotland alone, is spun in Belgium and France, no English firm having yet been successful in its economical production. With the success that has attended the attempts to produce mule-spun worsted yarns still markedly in evidence, it will be a strange thing if Bradford does not seriously attempt and succeed in producing this most important woollen yarn.

The Dress Goods, Stuff, and Lining trade is almost wholly located in Bradford and district. In mohairs Bradford still has a practical monopoly, although the piece trade is threatened by the export of "tops" and "yarns" to Continental centres and the United States. In all hard stuffs

[1] Or even prior to this, as Arthur Young, in his "Travels in France prior to 1794," refers to France's supremacy in these goods.

Bradford still leads, although both the United States and the Continental centres are gradually becoming proficient in the manipulation of English and cross-bred wools of the long type. Roubaix is the great rival of Bradford, in France, and Gera-Greiz, Tittan, Barmen, Elberfeld, Meerane, and Glauchau in Germany. In the United States the mills were so much engaged in the production of bulk sorts in the home-grown wools that little endeavour was made to produce European fine styles until quite recently. To-day the mills of Passaic are producing fine dress goods second to none.

The supplies of raw materials are derived as follows:—Oldham and Bolton supply the cotton warps, usually spun from best Egyptian or Sea Island cotton, but sometimes from American; Asia Minor, the Cape, California, and to a small extent Australia, supply mohair; South America supplies alpaca, vicuna, and llama wool; India supplies cashmere and other wools; England, New Zealand, and South America supply long and cross-bred wool; and Australia, the Cape, and South America supply the fine Botany wools required.[1] Spun silks are now manufactured in Bradford and, close to, at Brighouse, the raw material largely coming from Asia and the latest from the Congo State; while the net silks required are obtained from Macclesfield, the Continent, or China and Japan.

The organization of spinning has been dealt with under the heading of the Worsted Industry. So many and varied are the materials and counts of yarn used by the dress

[1] Canadian merino wool is just beginning to appear in Bradford. In the U. S. A. some most useful "domestic" or "territory" wools are now grown.

goods manufacturer that it would be an economic impossibility for him to spin the yarns he requires; he must buy on the open market.

Cotton warps are delivered in Bradford in the "ball" or "chain" form, and are dressed in the factories on to the loom beam.[1] Mule-spun and delicate wool warps are sized and run directly on to the loom beam by the warpers and sizers, who supply the yarn at a definite price per pound on the loom beam. If it were possible to hank-dye and wind 1-40's cap-spun yarn without undue waste, Bradford would soon develop a coloured dress goods trade. As it is France still retains by far the greater part of this lucrative section of the industry, as Bradford is largely limited to piece-dyeing.

The dress goods manufacturer restricts his energies to the warping and dressing of his yarns and the weaving of the same. His looms may be plain looms, box looms (frequently boxes at one end only), dobby looms or jacquard looms. As the trade is very liable to violent fluctuations from figured styles to plain styles, most fancy manufacturers make arrangements to sling their jacquards up and employ their looms as tappet or dobby looms as occasion demands. The looms used are largely made in the West Riding of Yorkshire. The number of looms in a shed will vary from 50 to 500 or even 1,000 with the accompanying warping, dressing, twisting, weft-room, and grey-room arrangements. The organization is comparatively simple as compared with a combing and spinning mill.

Some so-called manufacturers have no looms at all, getting their goods woven by "commission weavers."

[1] There is now a tendency for the spinner to deliver warp yarns ready dressed onto the loom beam.

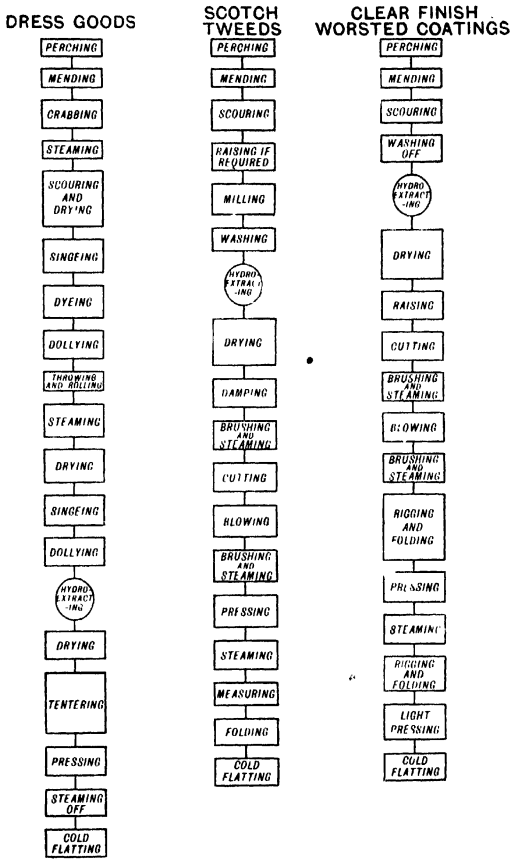


FIG. 62F.—Graphic Illustrations of Dress Goods, Scotch Tweeds, and Worsted Coatings Finishing Processes.

These firms are usually very limited in their turnover, although it is but fair to add that there have been some remarkable exceptions.

When figured goods are in fashion the designers and card-cutters form a very important section of the trade. The larger firms keep their own designing staff and card-cutters, but the smaller firms usually employ one of the independent public designing and card-cutting firms, who supply sketches to select from, point paper designs, and cut cards at a comparatively small price.

The styles of fabrics produced range from plain cloths to elaborate figures. The following particulars respecting (1) a plain lustre fabric; (2) a figured lustre fabric; (3) an all-wool Botany dress serge (cap-spun); (4) an Amazon or soft dress fabric; and (5) a Botany Italian, will give a good idea of the variety of texture to be met with in this trade.

1. *Plain Lustre Fabric:*

Warp.	*Weft.*
All 2/80's Egyptian or Sea Island Black cotton.	All 1/12's Grey Mohair or Lustre English.
40's reed 1's = 40 threads per inch.	46 picks per inch.

Cross-dyed black, lustre finish.

2. *Figured Lustre Fabric: Ground weave plain.*

Warp.	*Weft.*
All 2/100's bleached Egyptian or Sea Island cotton.	All 1/32's White Mohair.
32's reed 2's or 64's reed 1's = 64 threads per inch.	72 to 76 picks per inch.

Finished White.

3. *All-Wool Serge: Weave 2/2 Twill.*

Warp.	*Weft.*
All 2/56's Cap-Spun Botany.	All 1/30's Botany.
16's reed 4's = 64 threads per inch.	64 picks per inch.

Dyed any shade required, and given ordinary serge finish.

4. *Amazon: Weave: reverse 5 Sateen Warp Face.*

Warp.	*Weft.*
All 2/56's Cap-Spun Botany, or 1/30's Mule-Spun Botany.	All 40 Skein Woollen. 36 to 40 picks per inch.
24's reed 3's = 72 threads per inch.	

Dyed any shade required, and given a Venetian or Doeskin finish.

5. *Italian: Weave: 5 Sateen Weft Face.*

Warp.	*Weft.*
All 2/50's Black Cotton.	All 1/60's Botany (grey).
20's reed 4's.	120 picks per inch.

Dyed black, and given a solid lustrous Italian finish.

The finishing of dress fabrics, etc., is almost wholly in the hands of the Bradford Dyers' Association, although, as previously remarked, there are a few not altogether unimportant firms outside the combine. If the combine has maintained prices at a high standard, it is but fair to add that they have made most marked advances in the methods of dealing with the large variety of goods continually pouring into their works, and, in addition, have introduced some new finishes of surpassing excellence. The Association is now actually indicating to spinners and manufacturers the selection of raw materials and spinning and weaving necessary to produce specific finished styles.

As in the case of the worsted coating industry, there are two marked divisions of the dress goods trade—the home

section and the export or shipping section. Again, some firms merchant their own goods, and others work in conjunction with the large merchant houses. Unfortunately, Bradford trade terms are not standardized as are Manchester terms, so that conditions of sale and purchase vary considerably—sometimes for the good of the industry, but upon the whole, to the detriment of the industry.

The recent development of Bradford's trade in mercerized goods is worthy of more than passing comment. When, between 1890 and 1900, Bradford first took up this trade it was supposed that it would ultimately drift into Lancashire. Although this has partly occurred, Bradford has considerably more than held its own, and to-day is making large quantities of these goods for both the home market and for export. Of course this trade has cut at the spun silk and in part at the Italian industry, but upon the whole the gain has been much greater than the loss.

Artificial silk manufacturing also seems to have largely centred in Yorkshire, to-day large quantities of these goods being produced, more particularly in the Bradford district.

CHAPTER XIV

THE TAPESTRY AND CARPET INDUSTRY

The tapestry and carpet industries are frequently but not always allied. It is but natural that we should be able to trace the arts of tapestry and carpet weaving more definitely and perhaps farther back than the art of weaving ordinary fabrics, which, being simpler, did not claim the attention that the production of elaborate tent drapings claimed in the early days of the human race. As already pointed out, it was but natural that elaborate figure weaving should early develop in the family period of the industry, and that elaborate styles of an artistic character, unsurpassed even in these days, were to be met with not only in the eastern but also on the outskirts of the western Roman Empire. The Normans, for example, controlling the labour of England, built cathedrals and churches; in Sicily they not only caused churches to be built, but most elaborate and inspirited tapestries to be woven.

The draw-boy loom was introduced into England from the East during the Middle Ages, and it was no doubt already largely employed on the Continent. This mechanism certainly facilitated the production of large repeating patterns to a very considerable extent. Early in the nineteenth century Jacquard, with some more or less important improvements on the machines of his predecessors

and contemporaries, produced what is known as the Jacquard loom, and about 1830 this machine was successfully combined with the power-loom and made almost as complete a success as the ordinary plain power-loom. So little was the success of the Jacquard power-loom known outside the Bradford district, however, that the writer well remembers in the year 1884 or 1885 a supposed authority in the trade questioning whether it ever could be a success as a power-loom, *i.e.*, twenty or thirty years after it was running by the hundred, or perhaps thousand, in the Bradford district. To-day the tapestry loom is a magnificently harmonised combination of Jacquard, dobby or tappets, box motion, letting-off and taking-up motion, and is employed upon the simplest kinds of tapestries, consisting of little more than reverse warp and weft sateens, up to imitations of the Gobelin tapestries. In Fig. 63 a standard tapestry structure is illustrated.

The carpet trade may be divided into three branches, viz., double-structure or Kidder or Scotch carpets, tufted carpets, and true pile carpets. Double-structure carpets, no doubt, had their origin in stoutly woven fabrics to be employed as floor coverings, probably in the first instance for the ladies' apartments of the old baronial castles in the place of rushes, etc. To make a stouter and better-wearing carpet would naturally lead to the weaving of two cloths together, and from this would come the idea of figuring by an interchange of the two cloths—back to face and face to back—the colourings of back and face fabrics being designed to give the utmost value to this change (see Fig. 64). A special form of the Jacquard loom

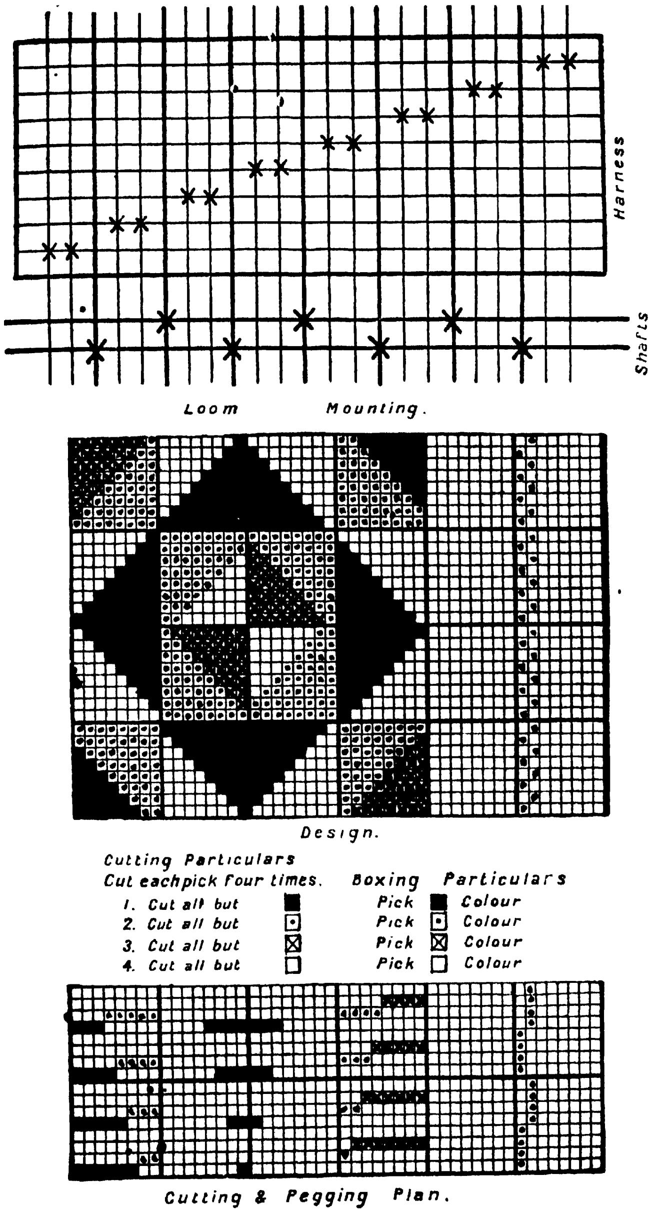


FIG. 63.—Simple Tapestry Structure and Design.

to facilitate the figuring of these goods was also a natural outcome.

Tufted carpets undoubtedly came to us from the East in the first case, Turkey carpets being probably known long before any attempts were made to produce such fabrics in western Europe. Largely owing to the definite endeavours of French statesmen—Colbert, for example—tufted fabrics were made in France during the sixteenth century, and from that date to this the noted Gobelin factory has been turning out most elaborate examples of these fabrics, in many cases reproducing with a most

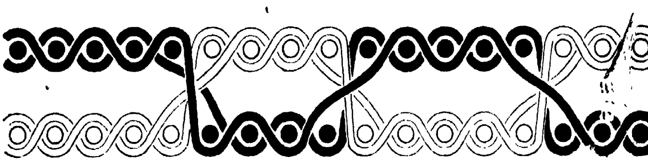


FIG. 64.—Scotch Carpet Structure.

wonderful exactitude the paintings of the most celebrated French artists. A more practical, if somewhat less artistic, hand-loom woven style of tufted carpet was developed during the seventeenth century, and owing to James I., in the seventeenth century, introducing this industry from Flanders into Axminster, in Devonshire, these carpets have become known as Axminster carpets. Briefly, they consist of a firm canvas back or foundation cloth—woven at the same time as the tufts are introduced—into which, row by row, tufts of the colours necessary to produce the pattern are firmly latched in by hand, and cut to the right length. Thus the only limit to this type of design is the

number of tufts which it is possible to insert across and lengthwise of the carpet. As these tufts are now introduced mechanically from bobbins held on bars mechanically presented across the " fell " of the piece, and as the number of bars from a practical point of view must be limited, so is the form design limited in both warp and weft direction (see Fig. 65). There is, however, no colour limitation save such as economy imposes. The Axminster power-loom was invented by Mr. Alexander Smith and Mr. Halcyon Skinner in the United States of America about the year 1856, but it took some twenty years to establish itself in this country. Many modifications of Axminster

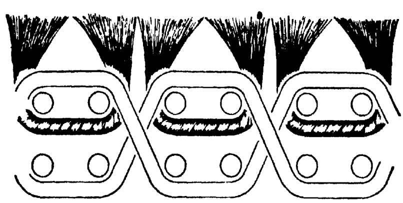


FIG. 65.—Axminster Carpet Structure.

carpets are now placed upon the market. In the most important of these the tufts of colour required in one line across the ultimate carpet are first woven into a gauze thread to form a " chenille " yarn, as many of these variously coloured tufted threads being woven and cut as is necessary to produce the pattern in the carpet, line by line. These are then most exactly woven along with the ground texture of the carpet, the loom throwing in, say, three ground picks, then the coloured chenille pick, and then stopping until the weaver has placed this in " register " to continue exactly the pattern already produced by the previous coloured chenille picks. Then the weaver touches a pedal and the loom again repeats

its four picks and stops. There are many varieties of these carpets, but such is the basis of structure and production of all.

How long wire pile carpets—now called Brussels, Wilton and Tapestry carpets—have been in vogue is difficult to estimate. As the name "Brussels" indicates, the industry originally came to us from Flanders, probably being introduced into Wilton in the year 1770, the development of this industry, as in the case of many other industries, being due in part to the definite interference and endeavours of certain of our sovereigns, and in part to the Continental religious persecutions, which drove skilled fugitives to our shores. Once here, it naturally spread, Glasgow, for example, probably receiving its carpet industry from Bristol by sea, just as Glasgow, in the early part of the nineteenth century, came across the Cashmere shawl from its shipping connection with the East, and evolved it as the "Paisley shawl." Of course, the first pile carpets were hand-woven, but in 1844 to 1850 the United States of America, always on the look-out for labour-saving contrivances, brought out the wire-loom (Bigelow's), in which every motion, from the shedding to the insertion of the wire, was controlled mechanically. Messrs. Crossley, of Halifax, soon took up this mechanism, and upon it built up a colossal concern. They were later followed by others, who applied the mechanism in a variety of ways. The three varieties of this structure are formed as follows:—The true looped Brussels is formed by looping wires and distinct coloured threads (or "frames") for every colour in each row lengthwise of the carpet (see Fig. 66). These coloured threads are lifted over the wires by the Jacquard (*i.e.*, lifted as

required for the insertion of the wires) to form the required pattern. The Wilton carpet is but a cut "Brussels" with certain slight modifications for example, a slightly modified ground structure and a longer pile. The tapestry carpet is produced from but one pile warp, this warp having the required pattern printed on it in an elongated form, so that when the take-up in weaving is effected by the wireing the right proportions for the true development of the design will result. As would be expected, the pattern is not so clearly

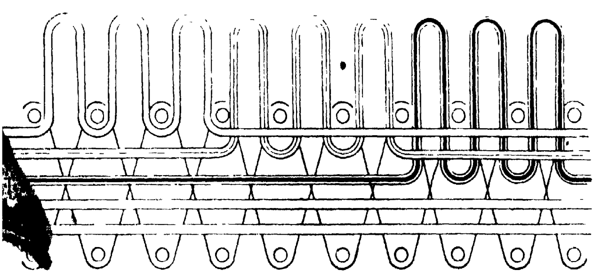


FIG. 66.—Three-frame Brussels Carpet Structure.

defined as in the Brussels or Wilton carpets, and as it does not contain so much material—having only one pile warp in place of several—it is not so elastic and consequently does not wear so well. The greatest defect of the Brussels and tapestry carpets is the tendency to "sprout," *i.e.*, to have long lengths of pile pulled out of them by a nail in a shoe, etc. This, of course, cannot occur with Axminster or Wilton carpets; hence their advantage. Well-woven Brussels carpets, however, should never develop this defect with fair usage. An interesting fact about Brussels, etc., carpets is that if they are not woven in squares they are

usually woven in widths of about twenty-seven inches, *i.e.*, the old Flemish ell and French aune.

The tapestry industry is dispersed over the country, being located principally in Halifax, Glasgow, Bradford, Carlisle, and also being instituted as a "home industry" in Ireland and England on very successful lines. On the Continent the centres are Paris, Roubaix, Berlin, Chemnitz, Crefeld and Vienna. In the United States, New York.

The carpet industry is largely located at Halifax, Glasgow, and Kidderminster in this country.

The materials consumed are silk (both net and spun), wool (chiefly English), mohair, hemp, jute, cotton and China grass.

The mill organization is naturally very elaborate and expensive. Messrs. John Crossley & Sons, of Halifax, for example, have premises extending over many acres and employ 5,000 work-people. They produce Brussels, tapestry and Axminster carpets. The firm of Messrs. James Morton & Co., of Carlisle, is remarkable chiefly because it has organized an elaborate Irish home industry for the production of many articles yet unproducible mechanically. There are some large carpet firms in the United States, and even Canada possesses a most progressive carpet manufacturing concern.

The methods of production, etc., so closely resemble the methods employed in the dress goods and stuffs industries that little further need be added. The designing room is, of course, pre-eminently important. The art of tapestry carpet designing, for example, is that of using the limitations of structure and colour as bases for design. Again, the

mixing, printing, and fastening of the colours upon the threads which are to form the pile in the carpet necessarily claim most marked attention. In Axminster carpet designing multitudinous gradations of every conceivable colour are conveniently arranged for the designer to select from.

Two branches, or rather sections, of the textile industry are not dealt with here, the hosiery industry and the ribbon, braid, and trimming industry. The hosiery industry has now attained to such dimensions and is so intimately associated with the stockinette frame and lace machine that it of necessity claims distinct treatment. The ribbon industry is so intimately connected with the bandolier, lace, and other narrow goods industry that it also is of sufficient importance to be considered as a distinct industry.

CHAPTER XV

SILK THROWING AND SPINNING

Silk manufacture has had the advantage during the last ten or twelve years of competent instruction in the technology of the raw material and its manipulation and weaving, together with its relationships to other textile fibres. The technical colleges of Manchester, Bradford, Leeds, and Macclesfield have made special arrangements and facilities for understanding the whole range of study from the production of the cocoon to the weaving of fabric.

In the scope of a single chapter it is impossible to attempt any detailed description of the various processes of rearing, reeling, throwing or spinning through which this interesting and beautiful fibre passes before it is fitted for the manufacturer, and we must therefore limit it to general characteristics, and especially as an important article of commerce, to the increase and improvement in character, with the causes which have led up to them.

That there has been an expansion will be seen later on by the figures showing the export from the various silk-producing countries, and the amount consumed by each great centre of manufacture. As far as our own country is concerned there is a general impression that silk weaving has materially decreased, and the closing of throwing

FIG. 67.—Silk Reeling, A.D. 1500.

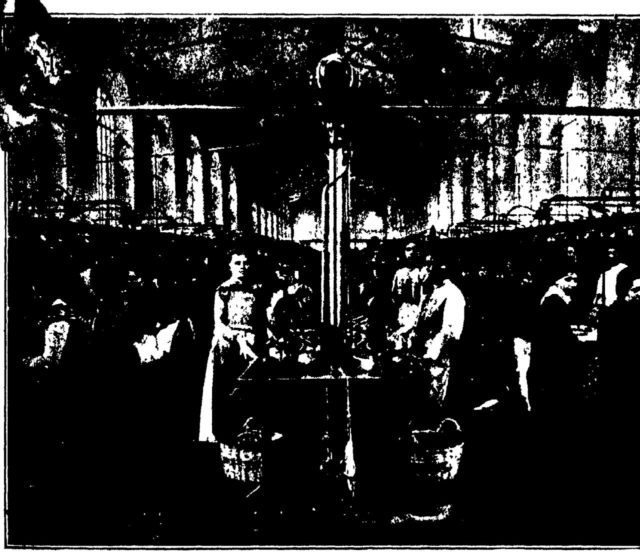


FIG. 68.—Silk Reeling, 1900.

By permission of Messrs. Giov. Battaglio, Laino, Italy.

mills and silk factories in Derby, Nottingham, Coventry, Macclesfield, and other towns gives colour to this conclusion. But it must be remembered that great economic changes have taken place during the last thirty to forty years. London is no longer the port of debarcation for the Eastern silks of China and Japan, and consequently the centre of distribution. The East India Company has ceased to hold responsibility for the importation and sale of our East Indian colony. The shipping companies now disembark their silk freights at Genoa and Marseilles as well as London, and the Japanese send a large contingent of their production across the Pacific to the American continent. Then, again, the evolution of the power-loom and its adaptation for silk weaving has practically displaced the occupation of the old hand-loom weaver, and by i[illegible] introduction a single operative will be producing four ti[illegible] the amount as in the former days by the older me[illegible] A general desire for cheap fabrics within the purc[illegible] power of the million has greatly stimulated the mixed goods trade, and the looms of Scotland, of Yorkshire, of Lancashire and other districts are now engaged in weaving this textile in combination with others, especially with mercerized cotton and wool. In spinning and throwing, by the introduction of better reeled silks, and the adoption of the faster running gravity spindle, the production has been nearly doubled, and consequently an equal weight is turned out with one half of the labour formerly employed. It is, of course, natural that those countries where the raw material is indigenous will endeavour to take a first place, or where, as in the case of America (a self-contained continent), a desire is manifest to retain the supply of its people in every

department of industry in its own hands, which they now do by a heavy protective tariff. In addition to their own consumption during recent years they have been able to export silk goods to England and other countries.

The following table of imports of raw silk for America from the years 1903 to end of 1919 shows the immense expansion of the silk industry in this country :—

During Years. Average per Annum.	1903	1904-1908.	1909-1913	1914-1918.	1919.
Asiatics	86,000	131,050	201,580	296,630	394,280
Europe and Levant .	27,490	39,420	30,610	4,330	17,200
Total in bales of 100 lbs. .	113,490	170,470	232,190	300,960	411,480

It will be seen from tables which follow of the world's [illegible]ction that America has taken some 80 per cent. of the [illegible]amount. The imports from Japan alone during the year 1919 have reached 90 per cent. of that country's exports.

The following table (p. 296) of silk production and export of the various countries where sericulture is carried on show clearly that the weight has been nearly trebled during the last fifty years.

These figures do not include the silk used by the natives of China, Japan or India. We know that they retain a very large contingent of their reelings, both for home consumption and export of fabrics.

Note.—This table requires some explanation. Up to the year 1884 statistics of the countries of Europe were grouped with those of the Levant and India. From that date up to the present time the yield in Italy, Austria and Hungary does

TABLE SHOWING SILK PRODUCTION AND EXPORT OF THE VARIOUS COUNTRIES (IN BALES OF 100 LBS. EACH).

During years Average per annum	From Europe.	Levant.	India.	China.	Canton.	Japan	Total.
1870 to 1874		105,250		56,915	19,110	14,400	195,675
1875 to 1879		78,320		67,520	17,666	17,560	181,066
1880 to 1884		109,400		63,050	18,090	24,970	215,510
1885 to 1889	90,700	14,670	17,330	56,715	23,200	41,860	244,475
1890 to 1894	93,580	17,760	5,775	68,585	28,510	58,505	272,715
1895 to 1899	93,820	20,700	7,160	77,900	43,300	72,375	324,195
1900 to 1904	93,525	46,635	6,050	96,435	46,280	98,630	387,555
1905 to 1909	122,470	60,750	6,335	102,300	47,895	140,460	480,210
1910 to 1914	101,583	53,209	3,533	121,035	49,839	223,441	552,640
1915 to 1919	70,092	20,790	2,354	104,984	46,816	312,796	557,832

not appear to have been materially increased, the average yield per annum being about 90,000 bales. The Levant (which includes Persia and Central Asia), taking an average, has more than doubled. The decrease during the 1915 to 1919 may be attributed to the effect of the W Asia Minor. India appears to show a decline of a serious nature. Up to 1889 the industry was protected and fostered by the control of the East India Company. After its withdrawal the decrease has been accentuated year by year, partly owing to the apathy of the native reelers, who preferred to reel the coarser silks for native manufacture, but mainly through the closing of the Bengal filatures worked by European capitalists. Their mills were employed for the production of silk suitable for export to Europe, but this proved unprofitable, owing to various economic conditions in India. The country manufactures more silk than it produces, so that it is difficult to ascertain its full complement of production. The Chinese exports have doubled as compared with those of fifty years

ago. During the last twenty years they have remained stationary at about 100,000 bales per annum. This only represents about one-half of their production; they retain fully 100,000 bales for home consumption. From 1885 to 1919 the Cantonese have doubled their exports, and by the establishment of filatures under European management they have improved the quality of the silk and increased the demand for it by American and European manufacturers. The greatest expansion in the world's production is attributable to the Japanese, which has more than trebled itself since the year 1900. This is owing to their extended cultivation of the mulberry and their improved methods of rearing and reeling. It is well known that their manufacturing requirements have increased in like proportion. The home demand and the manufacture of fabrics for export probably account for the ...ntion of at least one-third of the total yield in this country. The cause of this increased output is not attributable to ...le department of its cultivation and manipulation. All along the line Western science has been brought to bear, resulting in improved methods of rearing, reeling, and spinning. In France alone the production, which in the year 1820 reached 1,000,000 lbs., trebled itself during the following decade, and between the years 1840 and 1855 the estimated production was 4,500,000 lbs.; but this excessive development brought in its train serious consequences. The large breeders brought millions of worms together in one room, an overcrowding which induced a serious disease, and nearly threatened the extinction of the species throughout the whole of Southern Europe, and more or less in China and Japan, but without such serious results in these last-named countries.

This catastrophe, however, laid the foundation for greater

care in the breeding, and consequently for the better results of which we now reap the benefit. The whole world of sericulture will ever be indebted to M. Pasteur, who in the year 1865 was called to the rescue from what in France was looked upon as a national calamity. After two years of close study and experiment he succeeded in discovering and pointing out the cause of the malady and the means of preventing it. In the first place, healthy seed was imported from Japan, the country which had least suffered, and so the practice of cross-breeding became universal, and amongst the best "graineurs" to-day great care is exercised in the selection of the finest cocoons from the various districts in order to establish new and healthy breeds of silkworms. The main remedy was effected by the practice of "cellular incubation," viz., the examination of the eggs under the microscope, in order to ascertain if the production of each moth had within it the source of infectio[illegible] a future race. During the next ten years this meth[illegible] inspection was adopted by every well-ordered establishment, in every country, with the exception of the Chinese, who still suffer from year to year by their antiquated methods both in quality and quantity of the seasons' yield.

A book recently published by M'Laurent de L'Arbousset, of Alais, France, and translated from the French by Elizabeth Wardle, the talented daughter of the late Sir Thomas Wardle (President of the Silk Association of Great Britain and Ireland), reveals to us other causes of improvement than those of interbreeding and microscopical inspection, important as they are. The mulberry, the staple food of the *Bombyx mori*, is now cultivated under the most methodical and improved conditions, and calculated to afford the highest degree of nutrition. By careful selection

of healthy stock plants, grafting, pruning, and judicious gathering of the leaves, especially during the earlier growth, a more succulent and nourishing food is obtained and the trees are better able to resist the fungoid diseases to which they are liable. Magnaneries (rearing sheds) are more carefully warmed and ventilated, the silkworms are better spaced, and by cleanliness and mild fumigations of sulphurous acid or formalin the silkworms are kept freer from the diseases to which they are liable, and consequently spin a more robust cocoon, better in quality and the thread of greater length. In marketing the cocoons they are classified as to quality, and in stoving (with the object of killing the chrysalide) new and improved apparatus has been introduced. The peasants in country districts adopt very rimitive means of effecting this. One method described this writer is that of subjecting them to the baking ss. After the bread has been withdrawn from the 's oven, the bare arm is thrust into it, and, if the heat can be borne without scorching, the cocoons, placed in baskets, are then inserted and retained until the operator is satisfied that life no longer remains. Steaming, however, gives a much better quality of fibre, and in the absence of specially-constructed apparatus they are placed in baskets over a copper of boiling water, and after a complete desiccation spread out in the sun to dry thoroughly.

By the adoption of the foregoing methods the net yield from one ounce of graine, or eggs, has during the last twenty-five or thirty years been trebled, and in many instances quadrupled. It is now calculated that from this incubation of healthy and carefully-selected seed seventy

kilos of cocoons may be produced, 90 per cent. of which are of the first quality. But we pass on to note the stages by which the reeling has been brought up to its present standard of efficiency in the improvement of the reeled silk and the lowered cost of production. In the year 1820 a

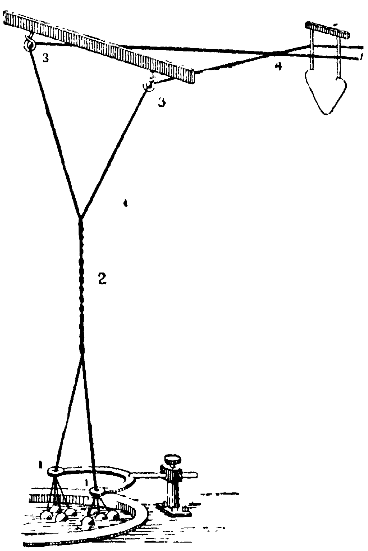


FIG. 69.—Croissure by the System Chambon.

French inventor, Gensoul, of Bagnols-sur-Lèze, introduced the process of heating the reeling basins by steam, which, by removing a separate oven for each basin and the driving of each reel separately by hand, enabled the workers to be placed nearer together on one table, and by one driving-wheel the whole line of reels are worked by the same motive power.

In 1828 a further improvement was introduced by Chambon, of Alais, which established the universal use of the Croissure which improved the reeled threads by making them rounder and more compact and homogeneous. Unfortunately this apparatus gave rise to what is known in the

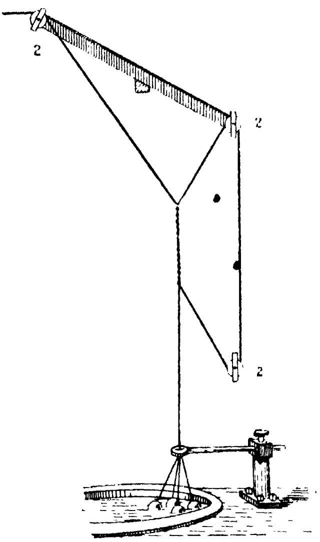


FIG. 70.—Croissure by Tavalette.

trade as "mariages," or double threads running parallel together on the reel and needing separation in the winding and throwing of the silk for manufacture. This has been obviated by the use of the Tavalette croissure, each separate thread being crossed upon itself (with thirty to forty turns), and is carried singly by means of small pulleys on to the reel. The waste material on the outside of the cocoon,

which had to be removed by the whisking of a brush in a separate basin, and by hand, is now effected by automatic machinery. The work of one reeler was under the older system confined to two sets of cocoons. (From four to six threads or cocoons are combined to make one thread of

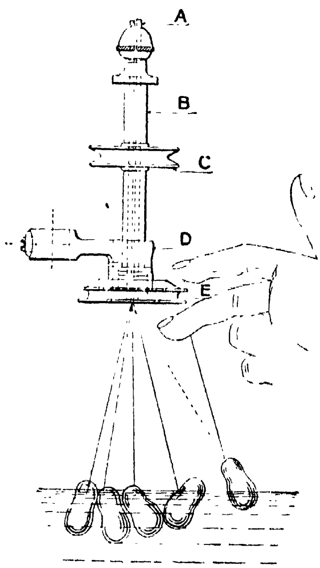


FIG. 71.—The Jette-bout, combining Five Cocoons in One Thread.

raw silk.) Now, under the new conditions, the reeler can easily superintend in one enlarged basin from four to six sets of cocoons, in addition to which the reels can be driven faster. In spite of the mechanical improvements in the apparatus used, it is necessary that great care should be exercised in order to avoid those defects which would impair

FIG. 72.—Duvet.

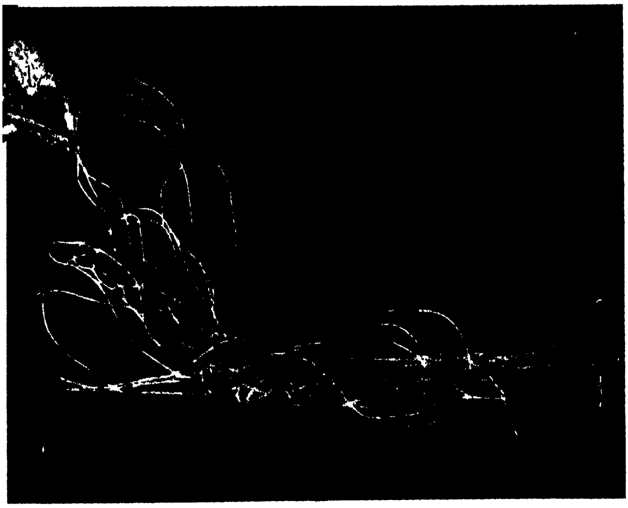


FIG. 73.—Bouchons or Slubs.

the quality or cause trouble in the weaving. A few of the imperfections to which bad reeling gives rise may be indicated. First, *Duvet* gives the appearance of short fibres thrown off from the main continuous thread. This was attributed formerly to the silkworm spinning an imperfect bave on the cocoon; but while there may be variation in thickness between the first and last end of the spun thread, there is no mechanical imperfection caused naturally. The microscope reveals to us the real cause, either frequent and

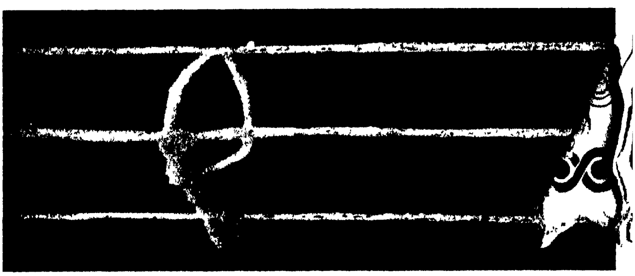


FIG. 71.—Knots.

imperfect joinings as the cocoons become attached to the main thread, or still more by an uneven temperature in the reeling basin (which should be kept at 140° to 160° Fahr.), thus causing the silk to unwind itself unevenly and cause small loops. Secondly, *Foul* or *Slubs* (bouchons) present a more aggravated form of the above-named defect, the layers of the thread on the cocoon coming off *en masse*. There are few productions actually free from this fault, and the native reelers of China silks are so careless that it is only by passing the thread through cleaners (steel blades

closed so as to stop the bouchons) that their productions can be utilized Thirdly, *Knots* are unavoidable, but by careful oversight they may be minimized, and under any circumstances be neatly made. Fourthly, *Baves* imperfectly joined together give the thread an open and soft appear-

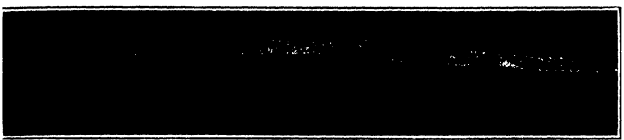


FIG. 75.—Baves imperfectly Joined

ance. They are mainly caused during a temporary stoppage of the reeling, some of the threads from the cocoon drying more quickly than others. Fifthly, *Vrilles* [illegible] the thread a creped appearance, and are produced by [illegible]eakage of one of the baves when it is necessary to [illegible] the number of the cocoons.

FIG. 76.—Vrilles.

Most of these faults may be discerned while the silk is in the raw or gum state. During the last decade a much graver imperfection (but not new by any means) has formed the subject of controversy amongst experts. It is known as *silk louse*, causing an appearance when discharged or dyed and wound on the bobbin of specks of dust. When

placed under a high power of the microscope these minute specks present the appearance of numberless fibrils indicating a rupture and division of the original bave and brin of the silk. It has been variously attributed to (*a*) the use of disinfectants in the rearing sheds chemically disin-

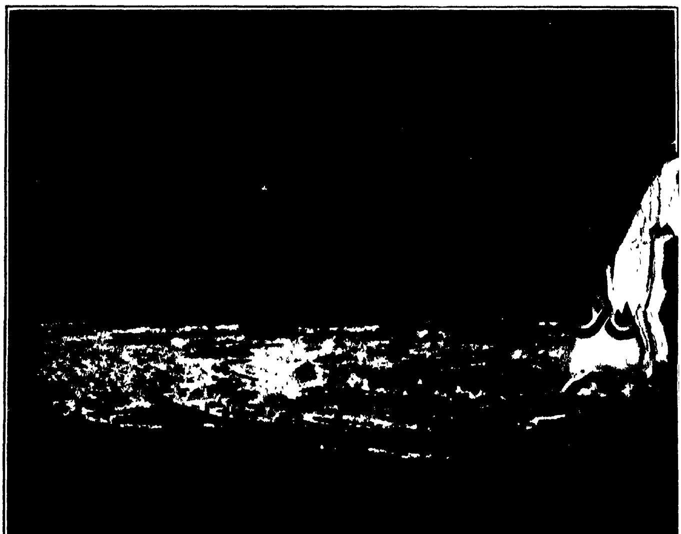


FIG. 77.—Silk-louse.

tegrating the fibre; (*b*) an imperfect croissure, the reeler failing to give the necessary number of turns of the thread upon itself; (*c*) undue punishment in the process of boiling, dyeing, or lustreing, specially the latter. So far no satisfactory solution has been arrived at, and it is most probable that it may arise from a combination of causes.

Certain it is that some classes of silk are more liable to it than others, and as the appearance is only spasmodic there may be certain seasons and countries where the conditions of rearing and reeling are unfavourable.

In the production of a good weaving thread it is equally necessary that the throwster should take every precaution either to minimize by cleaning the reeling defects of the raw silk, or, by good machinery and careful oversight in his own processes, avoid the production of faults incidental to this particular process of manipulation. A brief *résumé* of the work of the throwster may not be out of place. In dealing with the raw silk for throwing, the treatment should be varied according to quality. The filature silks of Italy, China, and Japan are fairly even in size, and the skeins are [illegible]led in hanks suited for winding without separation, [illegible]reas those of China reeled by the natives come to us in [illegible]s or hanks weighing nearly 1 lb., and require very care[illegible]plitting into smaller hanks. They are usually so uneven in the thickness of the thread that it is necessary to classify them, otherwise the union of a thick and thin thread produces in the two-folded tram or organzine a loopy or crinkled appearance, which is a serious fault and drawback to the after-processes in the manufacture. Where the silk in reeling has touched the arms of the reel a hard gum is formed, and requires carefully softening either by the immersion of that portion of the skein in a softening emulsion or by a complete washing of the bulk in a soap bath. The cost of winding varies according to the method of reeling. Those silks produced in well-equipped filatures or factories are as nearly perfect as possible, and one worker can superintend 80 to 100 spindles, the bobbin taking up

50 metres per minute, as against inferior native silks 20 to 25 spindles, and the waste caused by these latter is much heavier. In the next process of cleaning equal care is required, so that all the bouchons or foul may be eliminated,

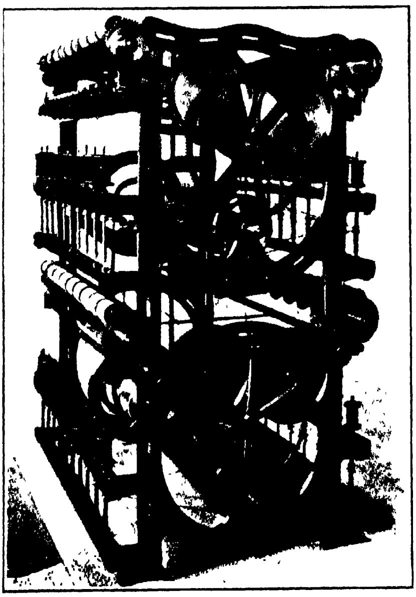


FIG. 78. The Ritson Spinning Mill.

and where tied out a neat knot should be made and the ends cut off shortly. The process of doubling two or more threads together requires equal vigilance. Two ends of equal size should be run together, the tensions on each carefully adjusted, and each thread passed through an automatic faller or eye, so that one thread cannot pass on to the

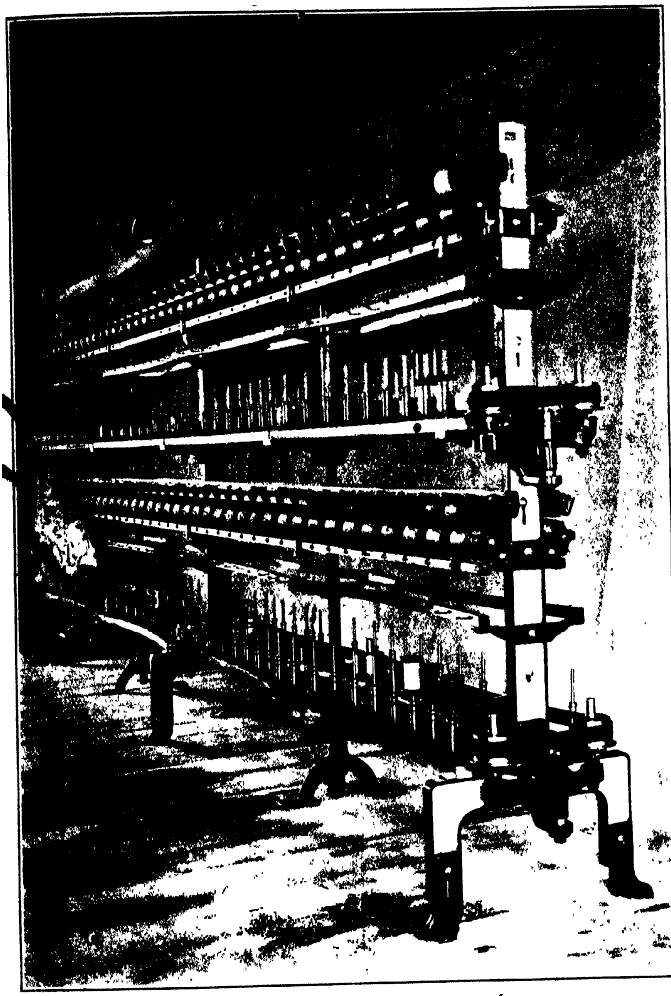


FIG. 79.—Spinner (new type).

bobbin singly. In spinning, doubling, and twisting marked improvements have been effected in late years by better and faster-running machinery. The Ritson spinning mill, introduced in 1830, with a separate cotton band for each spindle driven by a cylinder, was only capable of doing

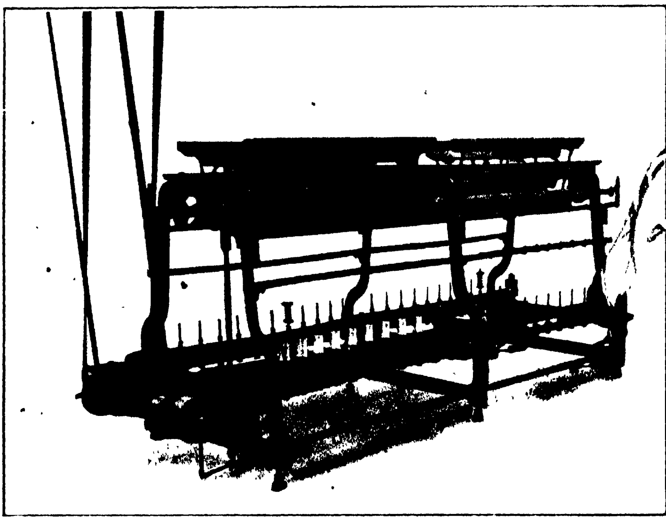


FIG. 80.—Throwing Mill, Twisting and Reeling Combined.

effective work at 3,000 to 4,000 revolutions of the spindle per minute.

This has been superseded by machinery furnished with gravity spindles, which are successfully run at the rate of 10,000 to 15,000 revolutions per minute. In addition to this advantage the machine only takes up two-thirds of the room of the older type. In some cases the final twist is given

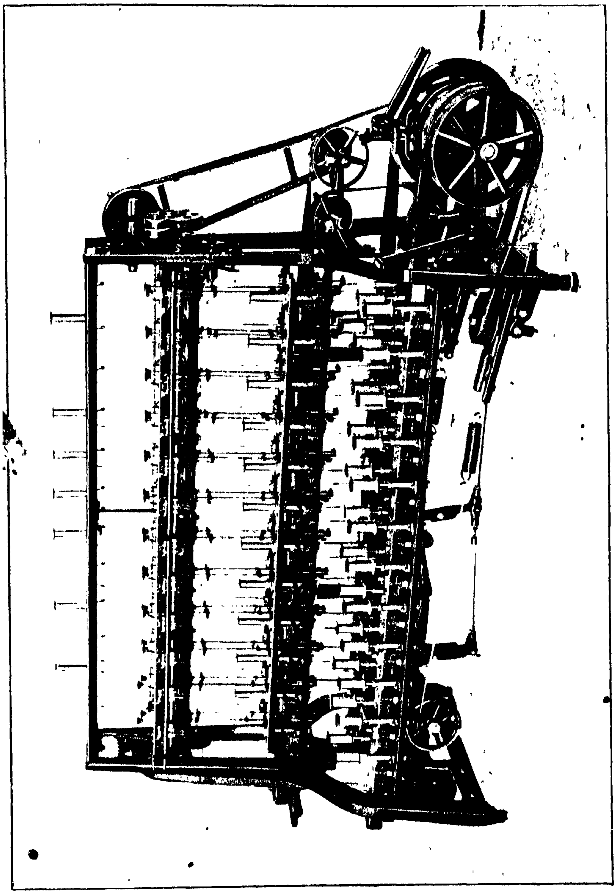


FIG. 81.—The Bradley Spinner Compound Processes.

on the same type of machine and the doubled thread reeled on a separate reeling machine with automatic stop motion, so that each skein is of an equal length. The more modern and equally effective method is to twist and reel at the same time. A twisting frame built on similar lines to that of the spinning mill, but with reels instead of take-up bobbins can be driven at the rate of 6,500 revolutions per minute. The latest American machine provides for spinning, doubling, and twisting in one process, but so far it can only be adapted for the most perfectly reeled silks of Italy and Japan of 14 to 16 deniers in the thread. Finer reeled silks and those of a commoner description would suffer in quality, and little if any advantage in cost would be gained by the adoption of so compounding the processes. One of the greatest advantages of late years has been gained by the process of cross-reeling known as the Grant system, by which a length of 5,000 to 10,000 yards can be reeled in one skein. The silk is kept straighter in the dyeing process, and the winding is facilitated, and at one-half of the original cost as against the smaller hanks.

As compared with other textiles made from short fibres, net silk has distinctive qualities which give to it a precedence over them. For instance, its natural brilliancy, transparency, and absorbent character enables the dyer to incorporate with it tannic acids or metallic salts, in some cases up to double its original weight, and increasing bulk up to 50 to 100 per cent., without in any way impairing its natural lustre, and at the same time so incorporating itself as part of the original thread that it is perfectly homogeneous, and not, as in some cases, appearing as an accretion outside of the thread or fibre itself. The properties of

elasticity and tenacity are also important factors, specially for weaving in the single thread without twist, as also those combinations where a strain is put upon the warp threads to produce certain effects.

Careful assays are made in what is known as conditioning houses to ensure to the buyer an article specially suited to his purpose. The absorbent quality admits of too great a percentage of moisture or water being incorporated with it when sold, in fact, up to 5 or 6 per cent. over the normal, without in any way appearing fraudulent. To arrive at a fair condition 500 or 600 grammes are carefully weighed, and afterwards enclosed for fifteen or twenty minutes in a specially constructed apparatus or oven, superheated up to about 300° Fahr. It is then weighed and 11 per cent. added to the absolute dry weight, by which percentage it is supposed that we arrive at the proper normal condition. A further test is added by decreusage or boiling off the gum in order to ascertain that no undue weighting of fatty or other matter has been added to increase the weight of silk beyond its original condition in the raw state. The tavelle, or winding test, is only applied in the case of raw silk as a guide to the silk throwster. Five hanks are placed on the winding swifts and run for two hours at the rate of 50 metres per minute on the take-up bobbin. The number of breakages during the time are carefully tabulated, and the resultant divided into 800 gives the number of spindles one worker can superintend. Tests for elasticity and tenacity are conducted on a special apparatus called the serimetre. The normal amount of elasticity indicating a silk of good quality should not be less than 25 per cent. of its length. Tenacity or amount of strain before breakage is considered

to be satisfactory if the weight borne in grammes is four times the denier or size of the thread. For example, a 10-12 denier raw silk should bear a strain of 40-50 grammes in weight (equivalent to about 1 oz. avoirdupois), and so on in proportion with all other sizes.

Assays for size or count are made by reeling 20 skeins of a given length, weighing each separately, which will indicate the range or variation, and thus showing the comparative evenness of the thread, or otherwise, and by striking a mean average of the totals the size or count will be ascertained, by which calculations may be built up for the manufacturer. An international metric count has been established in all silk centres as approved by the Paris Convention of 1900. This is based upon the metre for length, and the gramme for the weight—*e.g.*, No. 100 means that 100 metres will weigh one gramme. What is known as the legal count for raw and thrown silks is based upon the number of half decigrammes per 450 metres, and corresponds very nearly to the former method of weighing by the denier ($33\frac{1}{3}$ deniers = 1 dram avoirdupois) per 476 metres. The nomenclature for counts and sizes for various textiles is so varied that the student or manufacturer should furnish himself with the small handbook of "International Yarn Tables," compiled and arranged by McLennan, Blair & Co., of Glasgow, an absolutely indispensable office guide.

The question of the quality of the silks of various countries is varied according to climate, soil, rearing and reeling, etc., and can only be assessed by actual practice and by some knowledge of the various fabrics for which they are best suited. The question of grading and chops varies in the course of a

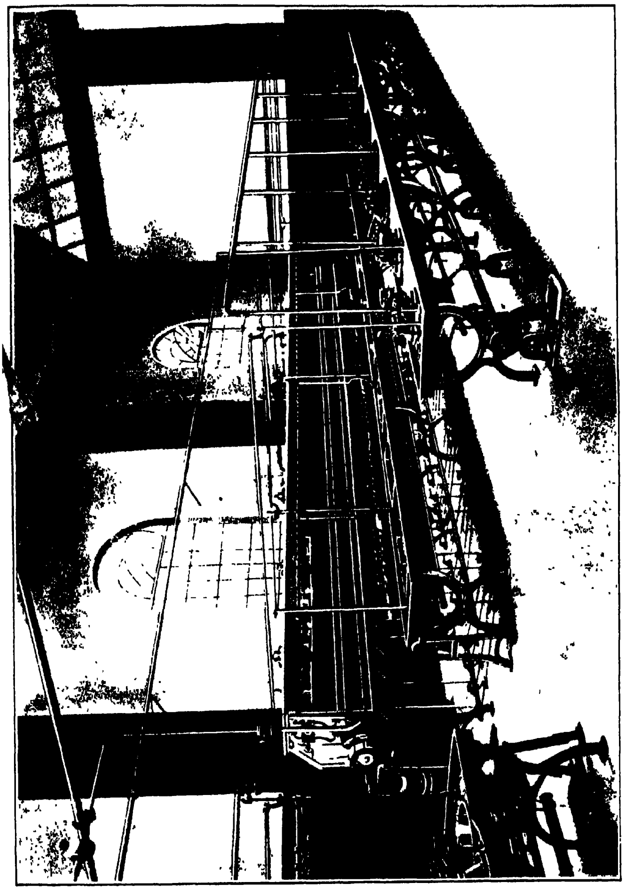


FIG. 82.—Silk Reeling Machinery at the Italian Exhibition of 1906.

few years. They are subject to expert inspection at the time of shipment, and those chops in favour at one period may take a secondary position later on. A few details respecting the various silks now imported may prove of interest.

French and Italian.—These are mostly yellow gum silks; in fact, the yellow breeds of cocoons are indigenous, and the eggs of the white races of the Far East, after a few years' breeding, revert to the yellow silks peculiar to these countries. They are usually reeled in stock sizes, from 9-11 to 14-16 deniers, for the purpose of throwing, and for special articles from 16-18 up to 30-32 deniers and even coarser, according to the number of cocoons reeled together to produce the desired size. Great care is exercised by the reeler to produce a well-formed and even thread. In this respect the Continental silks have secured a premier place in the world's markets. The range of size in a test of twenty skeins of 520 yards each, by the Milan official regulations, allow a range between the finest and coarsest threads of the following variations:—

Silks of 8-9 to 14-16 denier raws a range of 5 deniers, those of 18 to 24 deniers a range of 6 deniers, and those of 26 to 40 denier silks a range of 7 to 9 deniers. Owing to the dependence placed on these silks for evenness and cleanness, the finer deniers, 8-9 up to 14-16 deniers, are specially suited for organzine and trams, suitable for the manufacture of broad goods, glove fabrics, and for the best hosiery webs. The coarser reelings, 18-20 to 30-32 deniers, find a ready market for weaving in the raw, and for network in silk lace. The loss in boiling is about 25 per cent., but great care is required in discharging the gum, to avoid fluffiness or silk louse, to which they are somewhat liable if over-boiled. By a careful selection of cocoons, raws can be produced of different gradings

Fig. 83.—Interior of Kashmir Reeling Factory.

of quality and excellence. They are usually sold in the following degrees of merit:—(1) Exquis; (2) extra; (3) classic; (4) ordinary or sublime. The French reelers and throwsters grade their productions as follows:—(1) Extra; (2) first order; (3) second order, and (4) *ordinaire*. The productions of Spain, Austria and Hungary may be classed with those of France and Italy.

Syrian, Brutian, Bulgarian and Persian silks are also carefully reeled, and in similar sizes to those before named. They are, however, of a softer nature and not so well fitted for organzines as for tram silks. The coarser sizes of Bulgarian and Brutian silks are largely used for weaving in the gum (single thread). The finer sizes of Brutian and Persian silks, doubled two or three fold, make an excellent weft when twisted heavily for the manufacture of crêpe de chine.

Kashmir Silk.—In 1897 the industry in this province was non-existent. The Durbar of Kashmir invited Sir Thomas Wardle to initiate and develop sericulture in the district of Sringar, and under his superintendence healthy silkworm eggs were obtained from Europe and distributed to some 15,000 village householders for the rearing and cultivation of the mulberry. Taking an average of four persons for each family, it would appear that some 60,000 to 70,000 persons might be profitably employed. Factories were established for the reeling, and some 200 hand looms were sent out from this country for the weaving of fabrics, pongees and corahs, similar to those woven in Japan. In the year 1900 the annual production of raw silk was 57,921 lbs., and by the year 1906 it had increased to 190,736 lbs., and at that period there was every probability of a progressive increase. It has to be regretted that these expectations have not been fulfilled.

During the last ten years, owing to economic and other causes, the production has declined, and the 200 looms for weaving now remain idle. The owners found it impossible to compete with the better methods of the Japanese. The seed is imported annually from Europe, the race is univoltine. viz., one crop per annum, and the silk is much superior to the ordinary silks of India from the eastern provinces. Reeled in 10-12, 13-15 and 16-20 denier sizes, there is a ready market both on the Continent and in our own country for this class of silk for many purposes of manufacture. There is another district in the Punjaub producing silk of a similar character, and under like conditions, which is being imported under the title of "Soondor." This has been tested and approved by manufacturers, and an increase of production and exports would be welcomed.

Bengal Silks. The exports of the silk produced from the multivoltine species (three crops or bunds per annum) have declined to a negligible quantity, as will be seen from the tables previously given. The cultivation of the mulberry and of sericulture was principally carried out in the provinces of Mysore, Madras, Bengal and Assam. There are some possibilities of development in the first-named, but so far this hope has proved disappointing from various causes. The decline in the industry has been attributed to various causes. An important factor in the situation has been the withdrawal of European firms from the trade in recent years. Formerly these firms bought the cocoons, reeled the silk in filatures, and exported the raw silk and waste. With the fall in price for raw silk (before the war) the prices offered by the firms for cocoons did not attract sufficient supplies to keep the filatures employed, and the majority have been closed down. The

silks sold in Europe as Surdahs, Rangamatty Banjetty, Gonatea, etc., have entirely disappeared, and those called Rose filatures are the only ones known in the English market. Other factors have contributed to this decline: (*a*) excessive rent-charges for mulberry lands; (*b*) degeneration and disease of the worms; (*c*) competition of other crops; (*d*) want of cohesion and organization by the native reelers, who are mostly in the hands of middlemen. To these may be added a deterioration in the quality and winding of these silks as compared with the better productions of Japan. There is a good demand for silk for native manufacture, but the native reelings are being gradually displaced by importations of raw silk of low grades from China and Canton. The silks of the Bengal provinces being multivoltine the bave is finer, and the cocoon only yields two-thirds the length of the univoltine species. The thread is softer and more liable to dump, but it yields a bright thread after dyeing, and is especially suitable for weft, particularly when dyed black or dark colours. The sizes run from 10-11, 12-16 up to 16-20 deniers.

Cantons.—These also are the produce of multivoltines. The Cantonese produce six crops annually. The silk is similar in quality to the Bengals, but as the colour is a creamy white it lends itself to the lighter shades of colouring, and when well reeled is adapted particularly for crêpe de chine weft. Formerly this silk was all in the hands of native reelers, and very coarse and uneven. European enterprise and capital has established numberless filatures, and both for size, evenness and good winding properties they compete favourably with the filature silks of other countries. There are still some native reeled silks, but even these are of much better type than the exportations of twenty years ago. They are

mostly used for native manufacture and export to India. Only the best chops are now imported for European and American consumption.

From a recent inspection (1918-1919) the following may be taken as typical grades of these silks. They are reeled from 10-12 to 16-20 deniers :—

Extra.	*Best I.*
Anchor Chop.	Chung Wo Hing.
Loong Wing.	Hip Kee.
Tsung Wai Hang.	Kwong Hing Wo.
Wing Cheong Sing.	Moon Chop.
Petit Extra.	*Bon I.*
Chee Chung Wo.	Airship.
Chun Sun Hung.	Hip Lun.
Dragon and Phœnix.	Kwong Min Lun.
King Seng.	Wing Cheung Lun.
Best Star.	*First Order.*
Fat Kee.	Bamboo Chop.
Han King Lon.	Min Lun.
Kwong Tong Yuen.	Kwong Wo Ching.
Kum Lun Tai "Kittong."	Wing Cheong Hang.

As there are some 300 different chops in the importers' list those named are not given as being the best in each grade, but only typical of many others. There are still one or two imported as Best III., viz., Soey Wo Cheong and Yee Wo Ling, but as these native filatures are subject to "mariages" or double threads, caused by an imperfect croisure, and are very uneven in size they can only be used for lower-class goods.

"Japans."—These silks now form the most important factor in American and European imports. They have vastly improved during the last fifteen or twenty years, both for colour, reeling and general characteristics. They are good winding, fairly even, firm in the thread, and capable of being dyed and weighted (especially in colours) to double their

original weight (when boiled off). The sizes used for throwing in organzines and trams run from 8-9 to 14-16 deniers. During recent years the Japanese laid themselves out for the coarser deniers, suitable for weaving in the single thread. In the best grades we are able to import 16-18, 18-20 and even heavier sizes by arrangement with the importer. The American manufacturers use these silks more extensively than those of any other province or country. One special advantage of Japan silks is the minimum percentage of gum. The loss in boiling of the white silks does not exceed 18 to 20 per cent., as against European silks and those of India and Canton 25 per cent.

During the season 1918-1919 the Japanese imported European seed of the yellow races for special reeling. They produced a clean, bright and even thread of good tenacity and lustre, but as the loss in boiling was some 5 or 6 per cent. more than the white silk, and the colour not so well adapted for light shades, they could only command a secondary place in the market.

Although the production comes from various provinces, the bulk of our imports are named under the generic term of *Sinchus*. There are numberless chops (the trade mark of the reelers), but the classification for quality is much simpler, viz., Extras : Best I. : No. 1 : 1-1½ : 1½ : 1½-2 : Best II. The last two are only used in small quantities for European consumption; they are probably retained by the Japanese for home consumption. Another class of Japan filatures are the *Kakedahs*, reeled in sizes 10-12 to 14-16 denier, and are grouped as follows:—

Extra . . .	Kakedah Kimpai. Kintoke.
No. 1 . . .	Hime Daruma : Kinko.

No. $1\frac{1}{2}$ . . .	" One horse head."
No. 2	" Two horse heads."
No. 3 . . .	" Three horse heads."
No. 4	Botan, Nivatori, Okame.

There are also from another district the *Zangouris*, in different grades from a No. 1 to No. 2, but these are seldom on the market here. The best are reeled for America, and probably the lower grades are retained for home consumption. They are good white, boney silk, but not so well reeled as the Sinchus and Kakedahs.

China Silks cover so wide an area and are so varied in quality so that only general details can be included in this chapter, so must confine our description by a general classification.

(1) "*Steam Filatures*."—These are produced in factories in the neighbourhood or within a fifty-mile radius of Shanghai. They are reeled under European supervision and with the best methods of reeling, and, therefore, take a first place in the world's productions. They are white in colour, even in size, of a firm texture, and possess great tensile strength, so that for some branches of manufacture they are preferred to any other silk, and consequently command very high prices. The shipments of this class of Chinas during 1918-1919 season reached fully 30,000 bales, of which America took fully two-thirds of the exports. The sizes reeled run from 9-10 to 14-16 deniers for the purposes of throwing in organzine and tram, and heavier sizes, 16-18 to 24-26 deniers, for weaving purposes in the single thread.

From a recent table of classifications by a French importer we find there are some 200 available " chops " from which we select only a few typical ones from each grade.

Extra.

Sin Chong	Factory	Extra 1 and 2
Soey Lun	Anchor	Extra 1 and 2
Yang	Rayon d'or	Extra 1 and 2
Ewo filature	E.W.F.	Best 1 and 2
Young Tai	Double Deer	No. 1, 2 and 3

Petit Extra.

M. Denegri	M.D.	Extra 1 and 2
Yah Ha	W.T.K.	Extra 1 and 2
Yuen Lun	Centaure	Extra 1 and 2
Gee Sang	Bayard	Extra 1 and 2
Chue Len	Gold Mulberry Leaves	Extra 1 and 2

Best No. 1.

Yat Woo	Géranium	Extra 1 and 2
Ting Yue	Pasteur	Extra 1 and 2
Yah Sin Chong	Billiken	Extra 1 and 2
Chun Liung	Flying Lizards	1, 2 and 3
Shanghai Filature	Pegasus	Extra 1 and 2

No. 1.

Yat Kee	Arbutus	Extra 1 and 2
Yue Lun	Peacock	Extra 1 and 2
Lee Len	Field Marshal	Extra 1 and 2
Chue Len	Fountain	Extra 1 and 2
Yue Kong	Camelia	Extra 1 and 2

Best No. 2.

Yung Tai	Gold Globe	1, 2 and 3
Sin Kee	Chrysanthemum	Extra 1 and 2
Lun Kee	Airship	Extra 1 and 2
Tsun Nee	Flower Boat	Extra 1 and 2
Tsun Chong	Lotus	Extra 1 and 2

No. 2.

M. Denegri	Rose	Extra 1 and 2
Lee Chong	Gold Dollar	Extra 1 and 2
Yuen Chong	Lily	Extra 1 and 2
Pao Kee	Tramcar	Extra 1 and 2
Yun Kong	Carnation	Extra 1 and 2

Best 3.

Shing Wah	Double Fish and Dragon	1 and 2
Yer Keo	Begonia	Extra 1
Siu Lun	S.L.	Extra 1
Soo King	Woman and Loom	Extra 1
Chang Lun	Tramcar	Extra 1

" *No. 3 Ordinary Chops.*"

Yung Sin Chong	Moon	Extra 1
Tseng Lun	Gold Flying Tiger	Extra 1
Pao Woo	Lighthouse	1 and 2
Sing Dah	Flying Girl	1 and 2
Yang Lee	Shepherd	1 and 2

(2) " *Re-reels.*"—These silks are very similar to the native reeled silks, both as to size and quality. In fact, they are the native-reeled silks, wound by Chinese women, carefully cleared of some of the bouchons or foul by passing through the fingers, and by re-reeling a better winding is obtained. The finer and better portions of the silk are selected for this purpose, so that part of the cost of manipulation in silk-throwing is saved, a great desideratum at the present time, with the increased cost of labour and shorter hours of working. The exports during the last fifteen years have increased materially. From importers' statistics in the season 1914-1915 they reached fully 20,000 bales, more than four times the quantity of the ordinary native reels. The size in the raw is about 20 to 24 deniers.

To meet the American demand during the last fifteen years there has been an improvement in the style of reeling on the "Grant System," and these are now exported both to Europe and America under the designation "New Style." We append a list of a few of the best chops :—

New Style.

May Hun Ye.	Gold Eagle and Globe	Extra 1 and 2
May Hun Ye.	Gold Eagle and Bell	Extra 1 and 2
May Hun Ye.	Gold Swan	Extra 1 and 2

Tin Lung	Gold Flags Tripod	Extra 1 and 2
Ewo Yung	Gold Double Deer	Extra 1 and 2
Gee Kee	Gold Incense Burner	Extra 1 and 2
Yin Kee	Gold Kangaroo	Extra 1 and 2
Mai Hun Yue	Blue Dragon	Extra 1 and 2
Chu Yun Mur	Blue Monster	Extra 1 and 2
Gee Chong Lung	Star and Stripes	1, 2 and 3

The ordinary reel Tsatlee re-reels are still imported largely; these are not cross-reeled, therefore not so free winding, but they possess almost equal merit in quality as those of the "New style." They are classified as follows: —

Best Fine Size.

Crown, 1, 2, 3.
Gold Winding Mill, 1, 2, 3.
Gold Scale, 1, 2, 3.
Running Deer, 1, 2, 3.
Cloud Horse, 1, 2, 3.

Best.

Pegasus, 1, 2, 3.
Buffalo, A, B, C.
Red Dragon, 1, 2, 3.
Bicycle, A, B, C.
Red Fish, 1, 2, 3.
Grasshopper, A, B, C.
Black Horse, 1, 2, 3.
Double Red Eagle, 1, 2, 3.

No. 1.

Cloud and Dragon, 1, 2, 3.
Blue Lion, 1, 2, 3.
See May Zien, 1, 2, 3.
Gold Fish, 1, 2, 3.
Blue Pheasant, 1, 2, 3.

No. 2.

Gold Eagle, 1, 2, 3.
Spinning, 1, 2, 3.
Fan, Extra 1 and 2.
Sze She Shing.
Sze She Shing.
Chun Tai.
Show Yin Kee.
Yee Fong Zung Kee.
Hung Kee.
Mermaid, 1, 2, 3.
Three Josses, 1, 2, 3.
Magpie, 1, 2, 3.
Small Buffalo, 1 and 2.
SSS Mars, 1 and 2.
Gold Mars, 1 and 2.
Mars, 1 and 2.
Gold Unicorn, 1 and 2.
Double Crabs, 1 and 2.

No. 3.

Kung Kee.
Mars, 1.

The silks from the *Hainin district* (the size of which is much finer than the Tsatlees) are also re-reeled both in the new style and ordinary method. The colour of these silks is not so bright as those reeled from the Tsatlee district. The following are a few of the chops imported :—

	Best.	
Tuck Shing .	. Yellow Peacock .	. Extra 1 and 2
Tuck Shing .	. Blue Peacock .	. Extra 1 and 2
E. Tsun .	. Gold Pheasant .	. Extra 1 and 2
E. Tsun .	. Blue Pheasant .	Extra 1 and 2
E. Tsun .	. Music	. Extra 1 and 2
E. Tsun .	. Races	. Extra 1 and 2
Tuck Kee .	. Three Stars . .	Extra 1 and 2
Tuck Kee .	. Comet . . .	. Extra 1 and 2
	No. 1.	
King Woo .	. Green Flying Stork	. 1, 2, 3
Woo Nien Zung	. Chinese Volunteer .	. Extra 1 and 2

(3) "*Native Reels.*"—In the white silks these include Tsatlees, Kahings, Hainins and Hangchows. Owing to the selection of the best and finest hanks for re-reeling purposes the white native silks of China have greatly deteriorated. The increased cost of labour has caused a preference to be given to re-reels for European consumption. Tsatlees formerly constituted the main supply for the throwster. In the season 1914-1915 the export did not exceed 5,000 bales, and to-day it is still less. The Kahings, Hangchows, Woozies, etc., only find a very restricted export. The cocoons from these districts are bought up by the steam filatures for reeling in the factories of the Shanghai district. Naturally the cocoon of the white China species is second to none; in fact, if it could be produced under the same scientific conditions as those of Europe and Japan, for strength, lustre, etc., it would be the very best.

In the districts where the rearing takes place there is no microscopic selection of healthy graine or eggs, and consequently the worms are liable to the ravages of diseases to which the silkworm is subject.

The number of chops of Tsatlee silks and the gradings twenty years ago made quite an extensive list, but recent imports only include the following, which are given in order of quality :—Blue Elephant, Buffalo 3, Silver Double Elephant, Silver Electric Fan, Blue Double Elephant, Gold Lion, Gold Kiling, Choey Kiling, Red Kiling, and Running Deer. Ordinary reels have gone out of favour with European markets, and the above chops are practically all in which business is now done.

(4) *Yellow Silks.*—These are produced principally in the provinces of Shantung and the Seychuen districts. They were reeled formerly in large skeins 4 to 6 feet in circumference under different titles, and consequently difficult to wind. The silk was coarse, uneven and foul, and could only be utilized for sewings or very coarse fabrics. During the last eight or ten years native filatures and re-reels have been introduced, so that they are now coming into more extended use. The Shantung and Minchew filatures and re-reels are serviceable silks for many purposes of manufacture, especially where they can be used for darker colourings. The filatures are reeled in sizes from 12-15 to 16-18 deniers, and the winding of the best chops run from 50 to 70 tavelles. The re-reels run in sizes from 18-22 deniers to 22-28 deniers, and in the inferior qualities still coarser. The loss in boiling is fully 25 per cent. Reference as to chops and grades may be obtained from importers' classifications published by Messrs. Sulzer, Rudolph & Co., Messrs. Reiss & Co., and Messrs. Wm. Little & Co., of

Shanghai. The writer of this chapter is indebted to these firms for the chops named in connection with the White Chinas, as also to Mr. I. Gaillard, Shanghai, for steam filatures, and to Messrs. Gerin, Drevard & Co. for Cantons.

Duppions.—These are the produce of double cocoons. When the silkworm commences to form the cocoon it is essential that proper space should be given, otherwise where two of them come in close contact their spinnings are intertwined with each other and a double cocoon is formed. In reeling, the thread slubs off in a thick, irregular thread. The Italian duppion runs from 30-40 deniers and up to 80-100 deniers. The best reelings are thrown in Italy and Switzerland into sewing and embroidery threads. When cleaned by the racleuse machine and gassed a good article is produced. Not many of the Chinese or Japanese duppions are exported, being reserved for native use.

Wild Silks, produced in India by the Antherea Mylitta, in Northern China by the Antherea Pernyi, and in Japan by the Yama Mai species.—The first-named spin a thread of about 8 deniers in the bave, and has a good lustre when boiled off, but these silks are not in any demand by European throwsters. The Chinese products are exported to America and Europe under the title of Chefoo filatures, and have a good sale for the manufacture of Tussore silks. The bave is about 5 deniers, and they are reeled in 30-40 and 40-50 denier sizes. The silk from the Yama Mai is kept by the Japs for their own manufacture and embroideries. The grading of the Chefoo filatures vary from time to time, owing to change of ownership of the filatures, and possible deterioration in quality. From a 1918-1919 inspection by Messrs. William Little & Co., of Shanghai, we give a few of the best chops :—

Black Pagoda, 1 and 2.
Sun Flower, 1 and 2.
Gold Crown, 1 and 2.
Gold Joss, 1 and 2.
Dragon Fly, 1 and 2.
Apricot Flower, 1 and 2.
Gold Double Dragon, 1 and 2.
Black Fish Bowl, 1 and 2.
Chinese and American Flag, 1 and 2.
Japanese and American Flag, 1 and 2.
Sun Pagoda, 1 and 2.
Lucky Boy, 1 and 2.
George Washington, 1 and 2.
Mow San Peony, 1 and 2.
Spinning Girl, 1 and 2.
Poppies, 1 and 2.
Gold Bat, 1 and 2.
Black Monkey, 1 and 2.
Bamboo, 1 and 2.
Bamboo, 1 and 2.

So far we have only dealt with the silk in the net or raw state, and its manipulation in the processes of reeling and throwing, but in these stages it is estimated that an equal quantity of waste is produced, and which is now utilized for silk spinning. In the rearing of the cocoons the blaze or fine silken fibres thrown off by the silkworm on the bush as a nest on which to form its cocoon is collected, and China alone has exported 240,000 lbs. annually of this product. Imperfect and pierced cocoons which cannot be used for reeling form another source of supply. In the reeling process, before a perfect thread can be obtained for continuous running the outside threads are brushed off by an automatic process, and at least 25 to 30 per cent. of the total weight of the cocoon goes into the waste basket. To this may be added the waste made by the silk throwster in the processes of winding, cleaning, and doubling. Doubtless some portions of these waste materials were used by the ancients for all time, but under earlier conditions were combed and spun by hand. In the regulations of the thirteenth and fourteenth centuries in France mention is made of galette flourin and filoselle, productions of hand spinning, and in 1815 a society was formed in Paris for the encourage-

ment of the industry on a larger scale and by mechanical means. At this period the waste was cut into short lengths and spun on lines similar to those then existent in the cotton spinning, but in 1830 special machinery was introduced for dealing with longer fibres, on the basis of the present system of the silk-spinning industry of to-day. To a paper read by Joseph Boden, Esq., silk merchant, of Manchester, before the Silk Association in February, 1905, we are indebted for information as to the rise and progress of this branch of textile industry in our own country. It appears that the first spinning mill established in England was in the year 1792, at Galgate, near Lancaster, but a quarter of a century elapsed before this example was followed to any extent by other firms.

On the Continent operations were commenced in Bâle about the year 1822, and from that period both at home and abroad it has made considerable progress and development. It may be interesting to know that an approximate estimate of the spun-silk spindles in the whole world may be put at about 660,000, spread over France, Switzerland, Italy, Germany, Austria, England, America, China, Japan, and India. The production may be taken roughly at 15,500,000 lbs. per annum, of which about 11,000,000 are produced on the Continent, 3,000,000 in England, and the remainder in other countries.

The predominance gained by the Continent may be partly accounted for by the cheaper labour employed, and an abundant water supply, so necessary for the purpose of schapping, and also more favourable treatment by the absence of restrictive factory regulations. By the method of schapping, in which a portion of the gum is retained,

the processes are somewhat cheapened, a larger yield is obtained, and for some purposes, specially where required for black dyeing, the yarn has a wider scope of utility for the manufacturer. The gum is partially removed by the process of maceration and fermentation or by chemical means. The English spinners succeed in spinning brighter and whiter yarns which, although higher in price, command a sale for purposes for which the Continental yarns are less suited, specially where brilliancy and clearness of colouring is desired for delicate tintings and for whites. The methods employed for schapping, for long spinning, and for what is known as short-spuns involve different treatment and special machinery, the details of which are so varied that a special chapter would be necessary to describe them even in the most general outline. My purpose has been to show the evolution of the silk industry from the smallest and crudest beginnings up to its present conditions of expansion and improvement.

CHAPTER XVI

THE COTTON INDUSTRY

THE cotton branch of the textile industry has increased at such a rate during the last century in all parts of the world, and has now arrived at such proportions, that it may safely be said to occupy the foremost position among the industrial arts.

It has more money invested in buildings, plant, and stock, and employs more workpeople, directly and indirectly, than any other manufacturing branch of trade in this, or probably any other country where manufactures are carried on.

It is supposed that the manufacture of cotton originated in India about 1100 B.C., and the method then used have practically remained the same, until within a comparatively recent date. The Hindoos spun yarn and manufactured material of as fine a quality as can be produced to-day in any Lancashire mill, equipped with the best and most modern machinery. In the course of ordinary events the trade in cotton and cotton goods spread westwards, until we find it in Italy in the fourteenth, Germany, Prussia and England in the sixteenth, France in the seventeenth, and in Russia in the eighteenth century.

The first reported importation of cotton into England was in the year 1298, and it was mainly used for candle-wick. Manchester goods, which were principally made from a mixture

of woollen and cotton, or linen and cotton, were first heard of in the year 1352.

The weight and value of the cotton used has reached an enormous amount, as will be seen from Table I., which has been compiled by the Cotton Spinners' Federation, for 1910.

TABLE I.

COUNTRY.	Number of Spindles.	Cotton Used. All Kinds.
		Bales.
Great Britain . .	43,151,713	3,462,823
Germany . .	9,191,940	1,661,180
France . . .	6,603,105	923,423
Austria . . .	3,581,434	705,007
Italy . . .	2,867,862	731,357
Switzerland . .	1,413,896	89,360
Belgium . . .	1,110,600	190,756
Japan . . .	1,356,713	1,068,000
Spain . . .	1,387,500	255,754
Portugal . .	388,000	86,936
Russia . .	2,361,513	548,892
Holland . . .	395,678	73,870
Sweden . . .	326,860	76,559
Norway . .	65,776	10,647
Denmark . .	48,101	20,143
Levant . . .	23,184	13,100
Egypt . . .	39,200	4,386
United States of America . .	26,242,000	4,987,000
Total . .	100,561,078	14,909,193

These returns do not include India, China and some other small producing countries.

It will be noticed that the consumption per spindle varies very considerably in the different countries; this, in most cases, arises from the difference in the counts spun.

It will be seen also that 43 per cent. of the total spindles are in the United Kingdom.

The greater part of the cotton used is American, as out

of the total of 14,909,193 bales used, 11,668,575 bales are of this variety.

The total production of American during the last season was 6,500,000,000 lbs. It is interesting to know that a little over a century ago an American ship which imported eight bags of cotton into Liverpool was seized on the grounds that so much cotton could not be produced in the United States.

The total world's production during the last twelve months is estimated at 8,000,000,000 lbs.

Particulars as to the number of looms and the amount of cloth produced in the various countries are not easy to obtain, but Table II. gives the fullest information obtainable in regard to the increases in production and reductions in wage costs of both cloth and yarn in the United Kingdom in the years 1856, 1880, and 1905.

Table II. is very interesting, as it shows that during the last half-century the weight of yarn produced has increased by 886·7 million lbs.

The hours worked have decreased by 7·5 per cent., and the labour cost per lb. of yarn has decreased by 55·8 per cent.

The production of cloth has increased by 7,950 million yards; the hours worked have decreased by 7·5 per cent., and the labour cost per yard has decreased by 24·36 per cent.

During the time these changes have been taking place the average wages of the operatives have increased by 94 per cent., as shown in Table III.

The changes in hours and wages during the war and since have not yet had time to show their effects, but they will certainly alter the amounts given in column 3, and there will be some drop in the production per spindle and loom.

TABLE II.

PRODUCTION AND COSTS OF COTTON YARNS AND CLOTHS IN THE UNITED KINGDOM.

	1850.	1880.	1905.
Raw Cotton Imports, millions of lbs.	1,023·8	1,629·2	2,203·5
Raw Cotton Exports, millions of lbs.	146·6	224·6	283·1
[1] Yarn Production, millions of lbs., average counts	745·6	1,194·0	1,632·3
Yarn Exported, millions of lbs.	182·0	215·7	205·0
Yarn for Home Consumption, millions of lbs., average counts	563·6	978·3	1,427·3
Cloth Production, millions of yards, average width	3,600·0	7,737·0	11,550·0
Cloth Exported, millions of yards	2,036·5	4,496·3	6,198·2
Number of Spindles	28,000,000	42 000,000	50,000,000
" Looms	300,000	550,000	700,000
" Operatives in weaving mills	175,000	246,000	306,000 [2]
" Operatives in spinning mills	205,000	240,000	211,000 [2]
Working Hours per Week	60	56½	55½
Average Weekly Wages, 17 classes of operatives	14s. 6d.	19s. 10d.	26s. 2d.
Operatives per 1,000 Spindles	7·3	5·7	4·2
Production of Yarn per operative per year, lbs.	3,637·0	4,975·0	7,736·0
Production of Cloth per Operative, yards	20,580	31,860	37,740
Production of Yarn per Spindle per Year, lbs., average counts	27·0	28·5	32·6
Production of Cloth per Loom per Year, yards, average width	12,000	14,250	16,500
Labour Cost per lb. of Yarn, average counts	2·4d.	2·0d.	1·06d.
Labour Cost per Yard of Cloth, average width	·55d.	·447d.	·416d.

[1] Taking an average of 15 per cent. waste. Stocks not taken into account.

[2] From latest published Blue Books, 1903.

Table III.

Average Weekly Wages of Cotton-Mill Operatives, Manchester and Oldham Districts.

	1856 60 hours per week s.	d.	1880. 56½ hours per week. s.	d.	1905 55½ hours per week. s.	d.
Scutcher	8	0	13	8	21	6
Card-room Overlooker	28	0	38	6	50	0
Drawing-frame Tenter	9	0	15	0	19	0
Spinners' Overlooker	26	0	40	0	50	0
Mule Spinners (average of fine, medium, and coarse)	21	1	33	6	45	0
Mule Piecers (average of fine, medium, and coarse)	8	3	10	8	14	10
Throstle Spinners	9	0	11	0	16	0
Doffers	6	0	9	0	8	0
Reelers	9	0	12	0	17	0
Winders	9	0	14	2	18	0
Warpers	23	0	33	0	15	4
Beamers	22	0	24	9	22	0
Doubling Overlookers	28	0	24	0	35	0
Doublers	9	0	12	0	16	0
Gassers	9	6	13	0	20	0
Weavers (average number of looms)	11	2	15	3	24	0
Average of above seventeen classes of Operatives	11	6	19	10	26	2
Comparison, calculated for number of hours worked	100		144		194	

The altered conditions of the operatives are further seen by a comparison of the cost of living during the periods given in Tables II. and III. The particulars regarding cost of food have been obtained from the books of one of the large Manchester hospitals, no other data being to hand.

Table IV.

Comparative Conditions of Cotton Mill Operatives in the United Kingdom.

	1856.	1880.	1905.
Total number of Operatives employed in Cotton Mills	380,000	486,000	523,000[1]
Number of Half-time Operatives	10,050	51,000	21,000[1]
Age of Children admitted to work Half Time	9 years.	10 years.	12 years.
Age of Children admitted to work Full Time	13 years.	13 years.	13 years.
	s. d.	s. d.	s. d.
Average House Rents	3 0	5 0	6 0
Paid by one of the Manchester Hospitals:—			
Meat, per lb.	0 7½	0 8	0 6
Flour, per doz. lbs.	2 6	2 0	1 2
Bread, per 4 lb. loaf	0 8½	0 7½	0 5½
Sugar, per lb.	0 7	0 3½	0 1¾
Tea, per lb.	4 6	2 0	1 4
Butter, per lb.	1 2	1 0	0 11

[1] From latest published Blue Books, 1903.

One very satisfactory feature in this table is the increase in the age at which children are allowed to commence work as half-timers. It is very probable that at a near date the system of half-time working will be abolished in the cotton trade, as has been done for some years in the engineering trade.

These increases in production have not arisen through any great mechanical invention, seeing that all the radical patents for spinning and weaving machinery are dated prior to 1825, with perhaps one or two exceptions, such as the Heileman Comber, the automatic feeder for openers and scutchers, or the piano feed-motion regulator.

Wyatt invented the drawing frame, and Kay the fly shuttle in 1738; Lewis Paul the card in 1748, and the clever doffing comb mechanism about 1750.

Hargreaves invented the spinning jenny in 1764, and Crompton the mule in 1779.

The scutcher was invented in 1797, to be improved by the addition of the lap-end by Mr. Creighton fifty years later, and the piano-feed regulator by Mr. Lord in 1862.

Holdsworth brought out his wonderful differential motion in 1830. It is so far back as 1825 that Richard Roberts invented his self-acting mule, and even the ring frame, which has made such tremendous strides during the last thirty years, was invented more than eighty years ago.

There has, however, been a steady improvement in the details of the various machines, and in the methods of production by the machine-makers, so that it is possible to run at much higher speeds, and for the operative to attend a much larger number of spindles than formerly.

A few of these improvements may be briefly mentioned :—

(1) The revolving flat card, in which the old rollers and clearers of the roller and clearer card, with the inconvenience and dirt, are replaced by a travelling apron of flats or combs. This machine has taken many years to secure universal adoption, but on account of the cleaner work produced and the less cost for attention it is now used in almost every case except for very low counts and waste; but it must be said that there are still many people who contend that the greater amount of waste made more than counteracts the saving in labour.

The percentage of waste in the roller and clearer card is generally about 2, whereas in the revolving flat card it is 5.

(2) Another great improvement is the presser used in connection with preparation frame spindles. This is a very simple but most effective addition to the spindle, and consists of the addition to the old flyer of a loose leg, to which is added a foot called a presser. The outer part, or leg, is heavier than the inner part, or foot, and during revolution the centrifugal force of the leg being greater than that of the foot causes an inward pressure on the bobbin, thus enabling the machine to make a bobbin which is not so liable to damage in the after-process, and also contains a much greater length of material. This improvement has tended, in a great degree, to the reduction of cost in the preparatory stages of spinning.

(3) The piano-feed regulator, patented in 1862 by Mr. Lord, is also worthy of notice. This invention has for its object the regulating of the lap. It consists of a number of pedals like the keys on a piano. These pedals "feel" the cotton, and if it is too thick or too thin they put into action a motion which decreases or increases the rate of feed, thus automatically adjusting the volume of cotton in accordance with the weight per yard decided upon.

(4) Another patent of importance is the "Rabbeth" spindle for ring spinning and doubling frames. When the ring frame was first introduced it had top and bottom bearings for the spindle, which required oiling every day. This, besides being troublesome, was liable to cause dirty yarn, and it was not possible to run the spindle at a greater speed than 5,000 revolutions per minute, whereas the "Rabbeth," or self-contained gravity spindle, only requires oiling about every two months, and even with an unbalanced bobbin will run steadily at 20,000 revolutions per minute,

a speed much higher than is required, the maximum speed at which the worker can attend to the frame being about 10,000 revolutions. It will readily be seen what a great effect this patent has had in increasing the production of yarn.

(5) Another patent is the cross-winding frame. This machine was rendered necessary mainly on account of the changes in the location of the spinning and the weaving mills, and to meet the different conditions existing between mule and ring spinning mills, as also the hostile foreign tariffs. These varied conditions made it necessary to be able to send the yarn from place to place with the smallest possible amount of tares.

(6) Then of late years we have had the introduction of the automatic feeder into the blowing-room. This machine automatically regulates the supply of cotton to the cylinder beater of the opener, and thus more regular laps of cotton are produced than formerly, besides reducing the cost of attention 50 per cent.

(7) For certain classes and qualities the yarn spun on the mule is still considered to be superior to that produced on the ring spinning frame, especially for the very fine counts. Although the self-acting mule was invented and introduced some considerable time previous to 1856, the main principles are still the same, and the same facts hold good that this machine has only been improved in its detail parts. One of the main advances is concerning the number of spindles per mule. In 1856 and 1905 they were 500 and 1,300 respectively.

(8) Finally, there is the introduction of the various new types of looms. Previous to these there had been no radical alterations in the design of the loom for more than

fifty years. The automatic loom has made rather slow progress in England up to the present time, but there is no doubt they have come to stay. When it is borne in mind that a weaver can only attend to six looms of the old type, as a maximum, whereas he can attend to twelve or more of the new type, it will be seen that these automatic looms have a future before them.

In 1856, the earliest period in the tables of comparison, on page 323, the average spinning mill was constructed on very unsatisfactory principles, and it would contain about 30,000 spindles.

The mills generally had narrow, low, dark and ill-ventilated rooms, and the sanitary arrangements were exceedingly poor and unsatisfactory.

The power was in some cases transmitted by means of a water wheel, but steam engines were more generally adopted. These engines were of the beam type, single condensing, with cylinders up to 60 ins. diameter, and 8 ft. stroke, running 20 to 30 revolutions per minute. The steam pressure was from 20 to 60 lbs. per square inch, and the consumption about 25 lbs. of steam, and 3½ to 5 lbs. of coal per indicated horse-power.

The power was transmitted to the various rooms by means of spur gearing.

The spinning spindles were either of the mule or flyer type, running at 6,000 and 3,500 revolutions per minute, and producing ·52 lbs. and ·4 lbs. of yarn average counts, 32*s*. per spindle per week of 60 hours respectively.

The cost of such a mill was from 45*s*. to 50*s*. per spindle, including buildings, boilers, engines, machinery, and accessories. The cost of a weaving shed was £15 per loom.

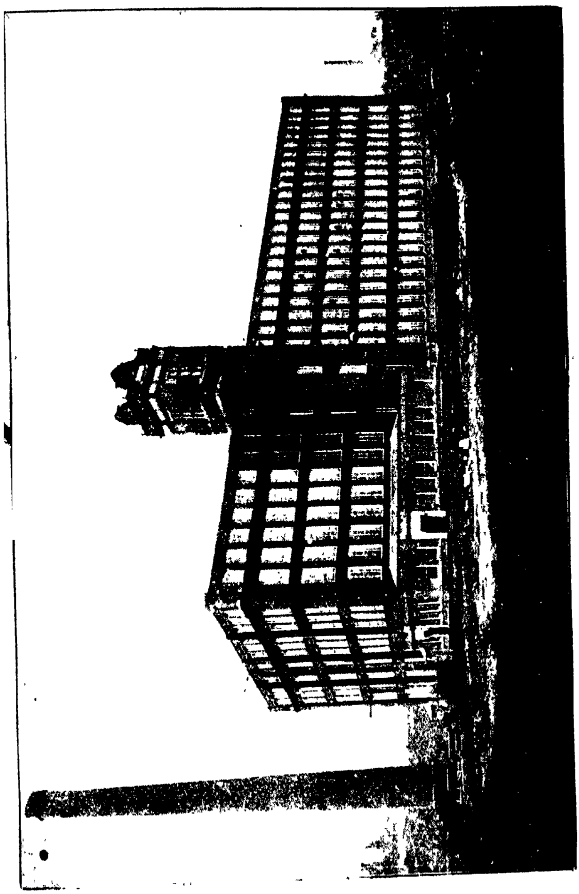


FIG. 84.—Modern Ring Spinning Mill.

At the present time the average mill contains about 80,000 spindles, and the yarn produced may be taken at an average of 40*s*. counts. The buildings are of the most approved design for cheap production and economical driving, and the sanitary arrangements are of the latest.

The machinery is so arranged that the raw cotton from the bale passes through the various machines until it arrives in the warehouse in the form of yarn, without traversing the same ground twice; that is, it pursues the shortest course possible to save cost in handling.

This is clearly shown on Fig. 84, which gives the arrangement of one of the most modern ring spinning mills, built in the shed form. This type has been adopted here because the whole of the processes in spinning and weaving can be clearly shown. In Fig. 85 a plan of a mill taking the cotton from the raw state to the finished product is given.

The power is mostly transmitted by steam engines, although great efforts are at present being made to introduce driving by electricity. Many mills in foreign countries have been arranged with this drive, particularly where there is a plentiful supply of water, which enables the engineer to install water turbo-generators, and to produce the electrical power much more cheaply than where steam is used.

Several mills have been fitted up in England recently with electrical driving, but the results have not yet been made public, so that it is not possible to say what prospects there are for this type of driving.

Steam turbines have also been installed into several mills with very satisfactory results.

Where steam engines are used they are of the recipro-

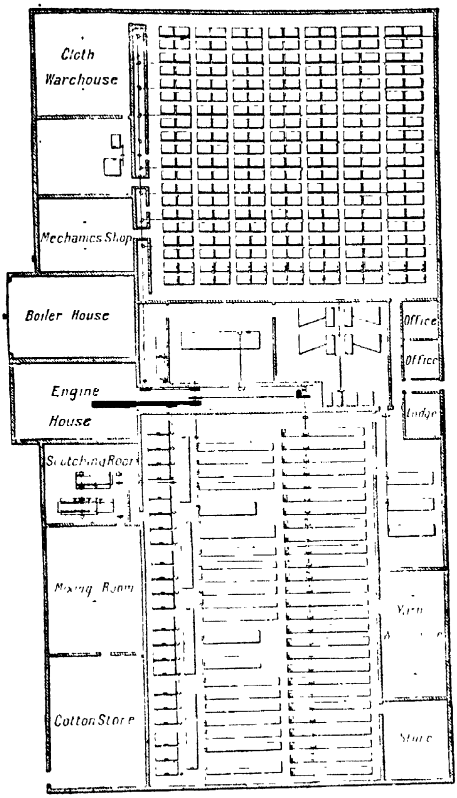


FIG. 85.—Plan of Cotton Mill.

cating type, either vertical or horizontal, with double, triple, and in some cases quadruple expansion, and of powers up to 2,500 indicated horse-power. The cylinders are made up to 66 in. diameter, with stroke up to 6 ft.

The crank shafts make 60 to 80 revolutions per minute, and are fitted with fly-wheels in the form of rope pulleys up to 30 ft. diameter, prepared to receive as many as fifty ropes of $1\frac{5}{8}$ in. diameter for driving the main shafts in the various rooms, thus dispensing with all spur gearing, giving greater freedom from breakdown, and much smoother and quieter running.

The steam consumption is from 12 to 16 lbs. of steam, and the coal consumption about $1\frac{1}{2}$ to 2 lbs. per indicated horse-power.

In cases where superheated steam is used the compound engine is about as economical as the triple expansion working under ordinary conditions.

The present mill hours are 48 per week.

The flyer frame has become almost obsolete, and the mills are either filled with ring or mule spindles, or in some cases both types of spinning machinery.

The speed of the spindles is—mule 11,000 revolutions, ring 9,500; and the production ·75 lbs. mule, and 1 lb. ring average counts 40*s*. per spindle per week respectively.

The various processes through which the cotton passes from the bales to the yarn or cloth are shown in the form of a diagram on page 331 (Fig. 86).

The cost of a mule mill in 1914 was about 23*s*. per spindle, and the cost of a ring mill from 38*s*. to 42*s*. per spindle inclusive; at the present time the cost would be at least three times as much.

The cost of a modern weaving shed is about £26 per loom.

Most of the extra cost per spindle in the ring mill arises from the greater production per spindle, which, as a consequence, requires more preparation machinery.

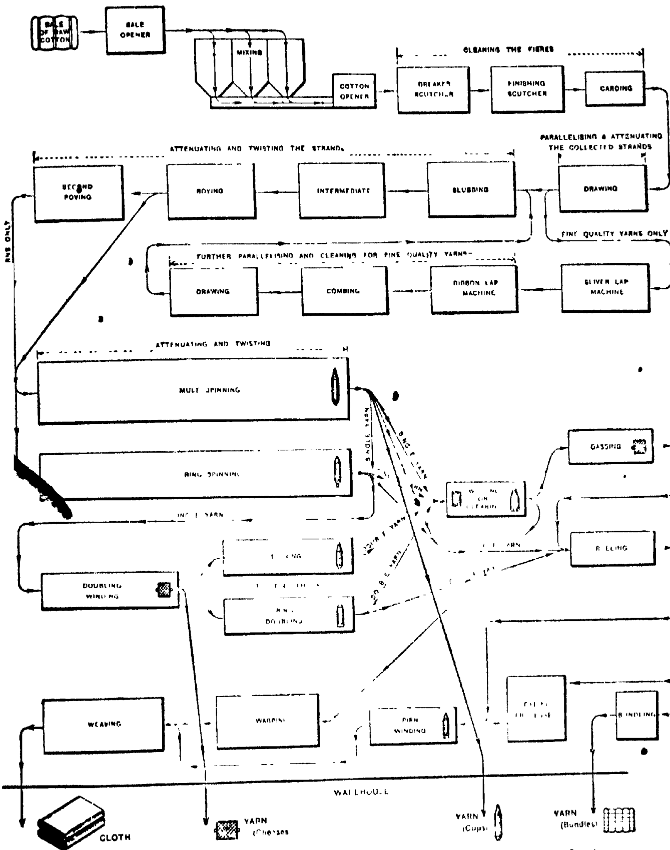


FIG. 86.—Graphic Illustration of Processes in Cotton Manufacture.

The greater cost of the modern weaving shed arises from the far superior manner in which it is fitted up.

The great reduction in the cost of erecting the modern

mill is further apparent when it is known that the average wages of the employees in the machine works have increased 12½ per cent., and the hours have been reduced 7½ per cent.

It has only been possible to do this by the introduction of labour-saving machinery of the highest type.

The machine construction branch of the textile industry is now so well organized that even with the heavy duties which are imposed by foreign countries the greater part of the machinery used in all parts of the world is produced in England, and there does not appear to be any reason to fear that for a long time to come England will lose her supremacy in either the machine-making or the spinning or manufacturing branch of the textile industry.

The whole of the textile industry and the businesses connected therewith are in a state of transition at the present time, wages having been increased to a large degree and hours considerably reduced. This makes it difficult to give anything definite in comparison with past years, but there is the certainty that, unless more mills are erected, the output will be much less than in 1914; how much, time alone can show.

CHAPTER XVII

THE LINEN INDUSTRY HISTORICALLY AND COMMERCIALLY CONSIDERED

THE cultivation of the flax plant, the separation of the fibres from the straw, the preparing and spinning of these same fibres into yarns, and their subsequent manufacture into linen cloth form to-day no insignificant branch of the textile industry, employing, as it does, tens of thousands of persons in the various progressive sections from the sowing of the flax seed to the distribution of the finished woven product.

EARLIEST RECORDS.

The Biblical records testify that flax was cultivated, yarn spun, and linen fabrics woven in the patriarchal times. It is also interesting to know that the manufacture of *fine linens* is spoken of in all classical records, books, and writings from the earliest times.

If the growth of flax, together with all the subsequent processes of preparation and manufacture into cloth, were considered from the point of antiquity alone, it would form an interesting volume, since most people manifest an

intense interest in anything which can justly claim to hav its foundation in prehistoric times.

Flax.—The first mention in the sacred writings of *flax* by that name occurs in connection with the plagues of Egypt (Ex. ix. 31): "And the *flax* and the barley were smitten, for the barley was in the ear and the flax was bolled." The virtuous woman is described by Solomon as one who "seeketh wool and *flax* and worketh it with her hands. . . . She layeth her hands to the spindle and her hands hold the distaff. . . . She maketh fine linen and selleth it" (Prov. xxxi. 13, 19, 24).

Scriptural Records: Linen.—The first scriptural record of *linen* described by that name is found in Gen. xli. 42: "And Pharaoh took off his ring from off his hand and put it upon Joseph's hand, and arrayed him in vestures of *fine linen*, and put a gold chain upon his neck." This was in 1715 B.C., when Pharaoh exalted Joseph to the second position in the kingdom. Though this is the first reference to *linen* in the Scriptures, it is very evident that linen fabrics were made long before this period, since the reference is to *fine* linen, and *fine* linen can only be manufactured after many efforts and long experience. The sackcloth which Jacob put on (Gen. xxxvii. 34), when Joseph's coat of many colours was brought to him, was in all probability made of coarse linen cloth. Some historians contend that coarse fabrics of flax were produced in the antediluvian age, and that the covering of Jabal's tents (Genesis iv. 20, 3875 B.C.) were made of some coarse flaxen or hempen material.

Linen—Emblematic of Purity.—Wherever cleanliness and purity were required the chosen symbol among fabrics

was linen, and in this respect it stands unique among all textile fabrics. Moses, in enumerating to the people the articles which might be offered for the fitting and completing of the tabernacle, says: "And blue and purple and scarlet and *fine linen* and goat's hair" (Ex. xxv. 4). Later, when Aaron and his sons were set apart as priests unto the people, instructions were given that Aaron's coat was to be embroidered in *fine linen*, and that his sons were to wear *linen* breeches. Further, whenever the Jewish priests entered in at the gates of the inner court of the sanctuary they were to be clothed with linen garments and no wool was to be upon them while they ministered within the gates. They were also to have linen bonnets upon their heads and linen breeches upon their loins during the ceremony, and were not to be girded with anything that causeth sweat (Ezek. xliv. 17, 18). St. John the Divine describes the seven angels as being clothed in pure white linen, and says: "For the fine linen is the righteousness of the saints;" and again: "The armies which were in heaven followed him upon white horses clothed in fine linen, white and clean."

Evolution of the Linen Manufacture.

Egypt—the Birthplace.—Historians generally agree that linen was first manufactured in Egypt. The flax plant was indigenous to the soil of Egypt, the climate and the Nile were favourable to its growth, and there appears to be no doubt as to its extensive cultivation in the earliest history of the country. It is an established fact that linen cloths were made in Egypt more than 4,000 years ago, specimens of the linen having been discovered in the land of the Pharaohs which were proved to be at least that

age. Solomon had *linen yarn* brought out of Egypt, and the king's merchants received the *linen yarn* at a price (2 Chron. i. 16).

As already intimated, many of the fabrics woven in those early times have been preserved unto the present day as a result of the practice, then common, of embalming the dead. The choice of linen for this purpose was due to the material being able to resist the development of animal life in a more marked degree than fabrics made from animal fibres, such as wool, which germinate animal life much sooner, and consequently would defeat the end they were intended to serve.

Many of the linens thus preserved were fine in texture, but "set" much closer in the warp than in the weft. This may be largely due to the method then practised of inserting the shuttle into the warp shed with the one hand and then receiving it at the opposite side by the other hand. Then, too, since there was no "lay" for beating up the weft, the operation had to be performed with the aid of a stick, which necessarily meant slow and tedious work, however skilful the weaver might be. Nevertheless, some few of the textures thus woven compare favourably with many modern productions. A specimen among these cloths in plain weave revealed as many as 90 threads per inch in the warp and 45 in the weft; a second contained 150 threads of warp with about 70 shots of weft per inch respectively, involving the use of yarns which exceeded 100 leas of 300 yards each per lb.—a fine yarn and sett! One specimen is recorded to have contained at least 250 double threads per inch, with half the number of weft threads for the same length. The ancient tombs of Egypt

reveal by pictures and other hieroglyphics the progressive stages through which the flax passed in those prehistoric times, and, singularly enough, the preparation of the fibre as then practised corresponds in many respects to the present method adopted, especially in Ireland. Some consider this an indication that the origin of the industry in the Emerald Isle was due to the migration of some Egyptians skilled in the art There are many evidences to show that the Egyptians produced more yarn than their looms could weave and more cloth than the people themselves could consume, which, combined with the fact that they were not a commercial or maritime people, gave an opportunity to the Phœnician traders, who navigated the high seas for thirteen centuries to distribute their yarns and woven products. Much of the latter was first delivered in Tyre, where the inhabitants dyed the fabrics in colours, for which they were famous, and afterwards the Phœnicians re-exported the goods to Persia, Arabia, Palestine, Greece, Italy, Spain and France, etc.

Decline of Linen Manufacture in Egypt.—Eventually, as the years rolled on the great enterprise hitherto displayed by the Egyptians in the peaceful arts and hereditary skill in textile crafts began to wane and gradually decayed.

Carthage, Babylon, and Greece.—With the advance of time, the renowned city of Carthage conducted the maritime commerce of the world, and discharged the duties of factor in *fine linens* as well as other textile materials. These goods they sent westward into the countries of Europe, including Britain. In Babylon and the whole region of the Euphrates the cultivation of flax was largely carried on, and the manufacture of linen was common in

all the cities on the banks of the Tigris; but this industry has long since become extinct in these countries. Greece had also a small share in the growth of flax and manufacture of linen, though she was never much noted in this respect.

Italy—Rome.—It is but natural to expect that Imperial Rome, exercising a world-wide influence, should seek to introduce into her country such a peaceful and profitable art as linen manufacturing. In her earliest days of conquest and supremacy she chiefly imported linens from the East. Subsequently she gave every encouragement to the manufacture of the finest linens in several parts of Italy. The most important step probably ever taken in this respect was when she formed guilds or colleges of the factories which were noted for the manufacture of the best qualities and varieties of linens. In these Imperial factories all kinds of clothing were made for the Emperor's family and court, and also for the officers and soldiers of the army. The guilds were also useful in collecting knowledge pertaining to the weavers' craft and of disseminating it by her legions throughout the whole of the Roman Empire.

Spain.—After the withdrawal of the Roman soldiers from Spain the Moors overran the country, yet it is recorded that they manufactured linens on an extensive scale and exported large quantities.

Germany and Austria.—Ever since the dawn of the seventh century the linen trade has had a home in Germany. It is one of its oldest branches of industry, and formerly ranked amongst its most important. In 1169 the Hanse towns of Hamburg, Lübeck, and Bremen formed a league

to protect their trade and commerce, of which linen products formed the most important section. The Hanseatic League existed for several centuries, during which time it distributed the linen manufactures of Germany throughout the chief centres of Europe. In sympathy with German manufacture, Austrian linens date from an early period.

France.—There was an extensive production of linens in Gaul at the time of the Roman domination of that country, and, notwithstanding all the vicissitudes of political fortune and revolution, the people have always carried on a considerable trade in the most delicate and finest of linens and other textile fabrics. This branch of the trade received its greatest check immediately following the Revocation of the Edict of Nantes, 1685, when the persecution of the Protestants became so acute that fully 600,000 skilled artisans, chiefly persons engaged in the textile trades, were obliged to leave their native land and seek refuge on other shores. About 70,000 of these refugees found a home in Great Britain or Ireland, and just as the woollen trade of Great Britain was materially assisted by the influx of these skilled artificers, so the linen trade of Ireland received its greatest impetus by their advent.

Various European Countries.—Other European countries, notably Holland and Belgium, carried on a large and important trade in linen for an extensive period. Belgium has always paid great attention to the cultivation of flax, and as far back as the tenth century she began to be famous for the manufacture of linen goods. On a somewhat smaller scale the flax plant was cultivated and linen cloth manufactured in other countries, notably Portugal, Denmark, Norway, Sweden, Switzerland, Turkey, and Russia.

United States of America.—The United States of America grows much flax, but its manufacture is, and always has been, comparatively small. To-day she is one of the best customers of Irish-made linens.

Great Britain and Ireland.

No historical description of the flax industry would be complete, however brief, unless some reference were made to Ireland, where to-day, and for at least seventy years, the production of flax yarns and manufacture of linens have stood out pre-eminently. Of necessity this industry in Ireland is inseparably linked to that of England and Scotland. In the traditional records of the "Four Masters" of the fifth century reference is made to "the weaves," "the flax scutching stick," "the distaff," etc.; the inference is left to the reader. The laws of the judges in Ireland, known as the ancient Brehon laws, required the farmers to learn the cultivation of flax.

The earliest authentic accounts of Irish linen manufacture date from the eleventh century, but the cloth made was only for home consumption, for the first exports occur in 1272, when it is recorded that Irish linen was used at Winchester. Generally speaking, England and Scotland acquired the art of linen manufacturing before Ireland. In 1253 Henry III. patronized English linens by ordering 1,000 ells for his wardrobe at Westminster. In the reign of Richard II. and the year 1382 a company of linen weavers, chiefly from the Netherlands, was established in London. But the climate and soil of Ireland were better adapted to the cultivation and growth of flax than those of Great Britain, and consequently she supplied the sister island with the

raw material. Later, about the middle of the seventeenth century, we learn that Ireland produced more flax and spun more yarn than she could weave, and as a consequence "The merchants of Manchester bought 'lynne yarne' from the Irish in great quantities, and after weaving it into cloth returned it to Ireland for sale."

About the year 1670 the English Government sought by every means in her power to encourage the linen industry of Ireland in its entirety It was not, however, until the seventeenth century was well advanced that the Irish linen trade attained any commercial importance. Then, owing largely to the Ulster colonists from Scotland, and later, the influx of the skilled French refugees, especially one Louis Crommelin, a wealthy Huguenot, who was induced to settle at Lisburn, near Belfast—the linen industry of Ireland made rapid progress. Crommelin, on the Revocation of the Edict of Nantes, fled first into Holland, where he became personally acquainted with William Prince of Orange, afterwards William III. of England, by whose persuasion he was subsequently induced to settle in Ireland. Here he spared no personal expense in introducing improvements for developing the linen industry, notably in regard to the spinning wheel and the loom, and involved himself in an expenditure of £10,000. For these valuable services he received a grant of £800 per annum, but owing to the death of his Royal patron, William III., the grant ceased after the second year. In the year 1712 a Royal Commission was appointed to enquire into the Irish linen trade, and reported that "Louis Crommelin and the Huguenot colony have been largely instrumental in improving and propagating the flaxen manufactures in the north of Ireland, and the perfection to which the same is

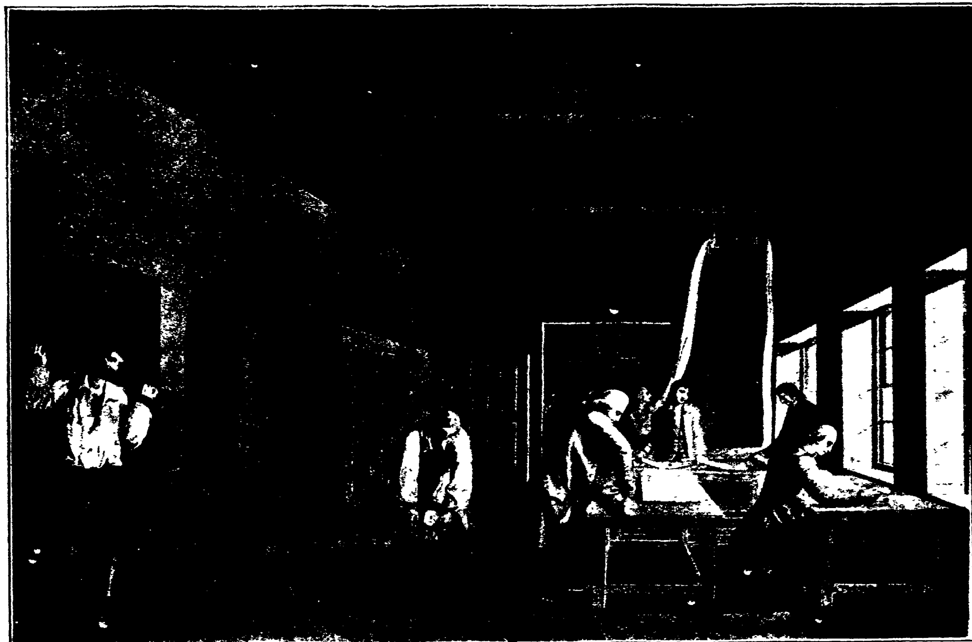


FIG. 87.—Perspective View of a Lapping Room in the olden times showing measuring, examining, folding the cloth into lengths, tying in the clips acting by the mechanical power of the lever to press the cloth round and firm, and *sealing* it preparatory to sending it to the Linen Hall.

brought in that part of the country is largely owing to the skill and industry of the said Crommelin." Crommelin's name, together with that of Philip de Gerard, the inventor of the wet-spinning process, is being still further perpetuated on panels in a stained-glass window devoted to the Textile Industries Department in the College of Technology, Belfast.

Linen Board of Ireland.—In 1711 the English Parliament created and endowed a Board of Trustees of linen and hempen manufacturers of Ireland to further encourage and develop the linen industry. During its existence the Board expended a sum of nearly £1,750,000 sterling from Imperial taxation for this purpose and the erection of a Linen Hall in Dublin. Upon the dissolution of the Board in 1828, Ireland had established her proud position in the world as an important linen manufacturing centre, and was fast displacing in the markets of the world the products of other linen-producing countries.

Sealing of Linens.—Among the many useful regulations imposed by the *Linen Board* was the introduction of an *Official Seal* for marking *white* linens before being exposed for sale, which resulted in a much-improved and superior-woven fabric. Guaranteeing as it did correctness of length and perfection of make, it inspired public confidence in all buyers of Irish linens. Subsequently the regulation stamp was extended to *brown* linens also with equally beneficial results. (For illustration see Fig. 87.)

Progress in Irish Linens.—By the year 1730 the trade had made such progress that in one month alone Ireland sent to the metropolis three times the length received by London from the whole of Holland; and so much did the

linen trade of Ireland prosper that foreign manufacturers of linens became greatly alarmed.

In 1689, when William III. ascended the throne, the export of Irish linens amounted to £12,000; in 1701 the amount reached £14,120; the fifth decade of the same century saw the total at £365,838 12*s*. 3*d*., so that in less than half a century the trade increased 250 per cent. If to this be added the export value of linen yarns for the same year the total value of linen exports reached half a million sterling.

In 1742 an import duty of 2*s*. 10*d*. per web was imposed on all foreign linens, and a bounty of 1*d*. per yard, later increased to 5*d*. per yard, on all British and Irish linens exported exceeding 1*s*. per yard encouraged the production of the finer fabrics.

Checks and Progress.—The linen trade of Ireland was not, however, of uninterrupted progress, for in the year 1773 about 30,000 people emigrated to America from Ulster alone, owing largely to trade being so bad. Yet statistics record that in the year 1784 the linen exports reached nearly 25 million yards, equal in value to about £1,250,000 and twelve years later the amount was practically double in quantity and value. At this time the finest linen cambrics sold at 25 guineas a web, equal to about one guinea per yard.

Modes of Exchange and Value: Eighteenth Century.—At this juncture it may be interesting to briefly consider values and methods of exchange of the period. In the year 1776 brown linens sold at 10½*d*. to 11*d*. per yard for 8^{00} (forty ends per inch). The weaver sold his web to a draper who usually possessed a bleach green; the cost of bleaching was from 3*s*. to 3*s*. 2*d*. per web, or 90*s*. to £5 per thirty pieces. When fully bleached the draper sent his material to London, the Linen

Hall at Dublin, or to Chester. In London, seven months' credit was given, in Dublin two to three months, and cash when the fabrics were sold personally and at all the local fairs (see Fig. 88). Spinners were paid 3*d.* to 4*d.* and weavers 10*d.* to 1*s.* 4*d.* per day. The setts ranged from 8^{00} to 21^{00}, and the prices paid for weaving were 8^{00}, $2\frac{1}{2}d.$; 10^{00}, $3\frac{1}{2}d.$; 13^{00}, $3\frac{3}{4}d.$; 16^{00}, 9*d.*; 18^{00}, $10\frac{3}{4}d.$; and 21^{00}, 1*s.* $7\frac{1}{2}d.$ per yard. The flax spinners were frequently engaged by the drapers at 10*s.* to 12*s.* per quarter, including board and lodging. They had to guarantee to turn off from five to eight hanks per week; usually an average spinner could spin six hanks (3,600 yards per hank) of 72's lea, *i.e.*, $72 \times 300 = 21{,}600$ yards per lb. The value of this yarn for an 18^{00} sett was worth approximately 8*d.* per hank, 4*s.* per lb., or 11*s.* 4*d.* per bundle. Belfast had two linen halls in which she conducted her exchanges, viz., the Brown Linen Hall in Donegall Street, originally built by Lord Donegall, now dismantled, and the White Linen Hall, originally built by subscription in Donegall Square, but now replaced by the magnificent City Hall.

Flax Cultivation, Harvesting, and Preparation. The flax plant is an annual and must, therefore, be cultivated; its natural tendency is to produce seed which may be used for subsequent sowing or harvested for feeding purposes only, but the market requires it chiefly for the fibre. The seed of this plant, for fibre purposes, must, therefore, be carefully selected and sown sufficiently profuse to ensure that the plant will grow up solitary, erect, and elegant in appearance, each piece terminating in a blue or white flower, which eventually develops into fruit bolls containing ten seeds.

The flax plant is made up of three parts: the skin, the fibres, and the pith or wood.

The fibres are found in concentric layers external to the pith

or wood, with which they are held in aggregate bundles by an adhesive or gummy substance— more correctly described as a *pectinous* compound—which may subsequently be dissolved by a process denominated retting, after which the fibre readily peels off if subjected to a beating process known as scutching.

The scutched flax is the raw material to the flax spinner. In this natural form it appears to be very long in fibre, but this length is only artificial, because the unit fibres are only about $1\frac{1}{2}$ to 2 inches long. They are held together in their natural and commercial state by the same pectinous compound which binds the fibres to the stem of the plant.

The unit or ultimate flax fibre is fine and strong, inelastic, but most durable. It is capable of being spun into a wide range of yarn numbers and sorts. Woven or knitted fabrics made from flax yarns are characterized by their propensity to absorb and readily give off moisture. They possess hygienic properties *par excellence*, and should consequently be frequently worn next to the skin. They are easy to wash and their characteristic clean appearance is always an inspiration.

The flax plant will grow in almost any climate and soil. The soil must be well prepared by ploughing and harrowing until a very fine tilth is acquired. A temperate and equable climate, free from heavy rains, frost or snow, is usually considered the most suitable for the cultivation of flax. In many countries the flax-growing districts are significantly adjacent to the sea.

In the British Isles the flax seed is sown from about April 1st to May 16th. The crop is usually ready for pulling in about twelve or thirteen weeks from the date of sowing. If there are many weeds in the growing crop they should always be pulled out by hand, when the young plants are 2, 3 or 4 inches high, because a flax crop must always be clean.

The young plants begin to bloom towards the end of June in the British Isles, and then the whole crop presents a mass of beautiful blue flowers. During the flowering period the plants shoot up rapidly, and add about 1 inch to their height every day. As soon as the flowers begin to fall the plant ceases to grow in length, but the seed bolls make their appearance and continue developing until they are globular in shape. At first the seed is milky and white-looking, but gradually it solidifies and passes from white through pale green to a brownish tint, at which period the flax is ready for pulling.

From time immemorial it has been the practice to pull flax up by the root and by hand, which, though simple and easy to learn, is slow and expensive.

At the present time numerous flax-pulling machines have been introduced; these are still in their experimental stage, but evidences are not wanting that in some instances the fundamental principles of mechanism have been established and only improvements in details await solution.

If the flax plants have been pulled for the twofold purpose of saving the seed for subsequent sowings or feeding purposes, in addition to securing its fibre, then the flax straw must be dried and de-seeded before anything further can be done to remove the flax fibre from the plant.

The removal of the fibres of the flax plant involves three distinct operations: (1) Retting, (2) drying, and (3) scutching.

The object of *retting* is to decompose by *fermentation* the pectinous compounds which bind the fibres to the stem. There are numerous methods of retting adopted at the present time; these include steeping the flax straw in ponds of stagnant water or in sluggish rivers, in concrete or wooden tanks. The Lys at Courtrai is a typical example of such a river. Retting is sometimes done in open fields by exposing the

flax to the dew, rain, snow, cold and heat, all of which factors combine to loosen the fibre from the stem. This is denominated "dew retting," and the process occupies about six weeks.

Pond retting requires from eight to sixteen days, according to the softness and temperature of the water. Warm water retting in tanks usually occupies from five to seven days.

When the flax is judged to be sufficiently retted it is taken out of the water and evenly spread or gaited in the fields until it is thoroughly dry. The dry retted flax is next, and finally, subjected to an operation technically denominated *scutching*. This operation is intended to break the pith or wooden matter in the straw by passing it between a series of fluted rollers. Subsequently the bruised straw is subjected to the beating action of a series of rotating wooden blades securely mounted on a steel shaft, which may be driven by hand, water or any form of mechanical power.

The yield of scutched flax to dry retted straw varies very much, and this may be due to one or many causes. The following are a few typical yields selected from practice:—

(1) Fresh pulled flax straw per statute acre, 4 to 5 tons; dry retted flax straw per statute acre, 25 to 30 cwt.; average yield of scutched flax per statute acre, 32 to 36 stones.

(2) Six hundred pounds of dry retted straw yielded 120 lbs. of scutched flax, 30 lbs of re-scutched tow.

(3) A farmer in Ireland in 1919 sowed 2 bushels of flax seed, from which he secured 47 stones of scutched flax, which was graded by the Government graders as No. 2 quality.

(4) The average pre-war return in Ireland was approximately 30 stones per statute acre.

Spinning and Weaving by Machinery.—The introduction of spinning and weaving by power, though difficult at first, gradually displaced to a considerable extent the hand method,

FIG. 88.—The Local Linen Fair at Banbridge, in County Down, Ireland, in the olden times. The weavers are holding up their webs of linen to view; the bleachers and buyers are elevated on forms examining its quality.

and also centralised the work in mills and factories. The spinning of flax by machinery was attempted in Great Britain fully a decade previous to any similar experiment in Ireland, notwithstanding that the latter country had acquired a considerable reputation for flax spinning. At

FIG. 89. —Loading flax.
From a photograph by A. F. Barker.

first it was only possible to produce by machinery the coarser and lower dry spun numbers of yarn. The first machines for this purpose were started in Cork, and later at Ballymena and Crumlin, in county Antrim, about the year 1787. The Irish Linen Board, which at that time was still in existence, sought to encourage the enterprise

by offering 30s. per spindle to the owners of all mills who introduced the power method, and by the year 1816 there were 6,369 spindles at work. The hand-spinning method for the finer yarns would, in all probability, have continued to this day but for the discovery of the wet-

FIG. 90.—Retting flax: putting flax in dam.
From a photograph by A. F. Barker.

spinning process by Philip de Gerard, of France, about the year 1826. This process was subsequently and successfully applied by Marshalls of Leeds, Baxter of Dundee, Mulholland of Belfast, and Murland of Castlewellan. In the year 1828 Messrs. Murland started the enterprise, and in the year following Messrs. Mulholland, now the York

Street Flax Spinning Mills, Belfast, adopted the new process, whereby it became possible, with the use of hot water, to soften the gummy matter which holds the flax fibres together, and reduce them to their ultimate length and fineness, and so to draw and spin them into yarn of a

FIG. 91.—Retting flax: taking flax out of dam after, say, ten days.
From a photograph by A. F. Barker.

much greater length and fineness than by the dry-spinning process. Undoubtedly the discovery and practical application of same thoroughly revolutionised the spinning, and eventually exerted an immense influence over the weaving, by causing a greater demand for power looms. Ireland now began more rapidly than ever to acquire the lead over

foreign linen-producing countries in the markets of the world; and Belfast, the centre of the Irish linen trade, not only maintained, but increased her proud position among the manufacturing centres, whilst to-day she ranks as both

FIG. 92.—Flax drying.—Stack after retting.
From a photograph by A. F. Barker.

the industrial capital of Ireland and the metropolis of the world's linen industrial centres.

Statistics do not show any considerable adoption of power looms prior to 1850, but the following abbreviated table will give some idea of the development in the spinning and weaving of linen throughout the country since the advent of machinery.

Year.	Number of Spindles in Ireland	Number of Power Looms.
1841	250,000	—
1850	326,000	58
1856	567,980	1,871
1866	770,814	10,804
1875	924,817	20,152
1900	843,931	32,245
1906	869,146	34,723
1907	909,999	35,386
1908	913,123	35,386
Feb., 1910	939,732	35,622

The following comparative latest pre-war official returns of spindles and power looms engaged in the linen industry in the United Kingdom and on the Continent will no doubt be interesting :—

Country	Number of Spindles	Number of Power Looms
Ireland	939,732	35,622
France	515,497	18,083
Scotland	160,085	17,185
Germany	325 000	7,557
Russia	300,000	7,312
England and Wales	49 911	4,421
Italy	[1] 77,000	3,500
Belgium	[1] 280,000	3,400
Austria-Hungary	294,000	3,357
Holland	8,000	1,200
Spain	-	1,000
Norway and Sweden		106
[2] Total for Europe	1,829,197	43,815
,, United Kingdom	1,120,025	56,995

[1] Flax and hemp. [2] Exclusive of the U. K.

The volume of linen *yarn* exported from the United Kingdom in 1906 reached the enormous total of

14,975,500 lbs., bearing a monetary value of £1,008,831. In the year 1840 the respective totals were 28,734,212 lbs. and £1,976,830, from which date there has been a gradual

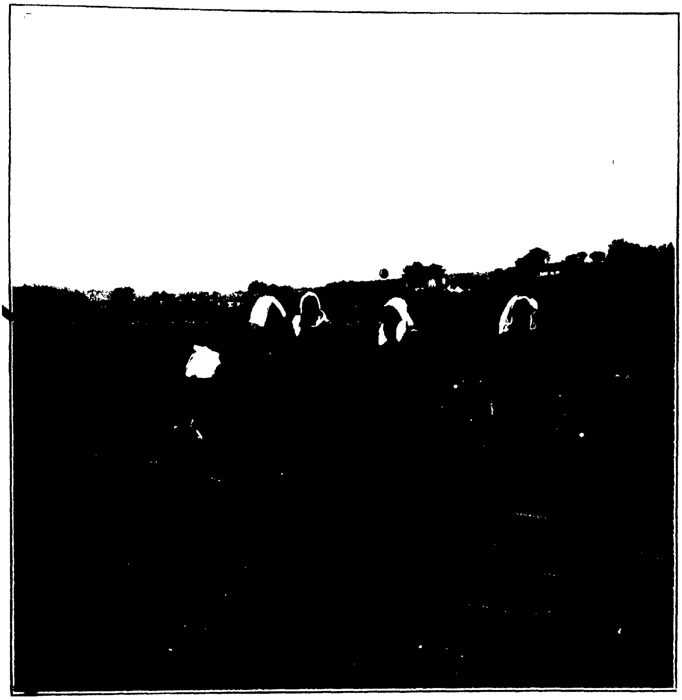


FIG. 93.—Flax spreading.
From a photograph by A. F. Barker.

decline as far as yarn exported was concerned, but an ever-increasing demand for home productions. The average annual imports of linen yarn into the United Kingdom

during the last decade reached 26,311,329 lbs. of declared value £933,426. These yarns are chiefly of the lower numbers. The linen *goods* of all kinds exported for the year 1906 amounted in value to £5,326,744, whilst the total value of linen yarns, threads, and piece goods reached £6,341,216.

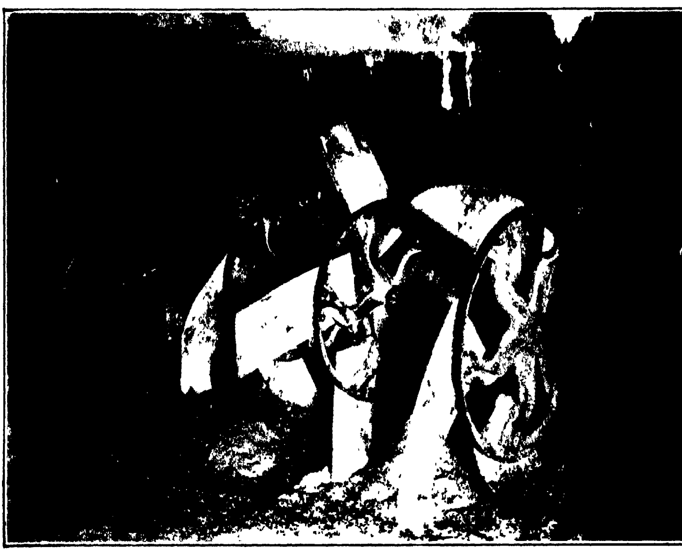


FIG. 94.—Inside an Irish Scutching Mill.
From a photograph by A. F. Barker.

These summarised Board of Trade returns, together with the large amount of linen used for home consumption, added to the fact that nearly 300,000 people in Great Britain and Ireland are exclusively engaged in the growth of flax, the preparation and spinning of long vegetable fibres

(flax, hemp, and jute), the manufacture and merchanting of linen yarns and fabrics, will afford some idea of the commercial importance to which this industry has now attained.

Linen Varieties.—The varieties of fabrics made from *flax* in respect to structure, design, quality, and finish is much

FIG. 95.—Inside an Irish Scutching Mill.
From a photograph by A. F. Barker.

greater to-day than formerly. These include plains, ducks, hollands, lawns, sheer lawns, cambrics, handkerchiefs, dress linens, and unions in an ever-increasing novelty, vestings, glass cloths, drills and diapers, huckabacks, honeycomb and Turkish towels, d'oyleys, napkins, and damasks. The world-renowned cambrics were first made at Cambrai,

in France, and the same country was famous for the initiation and manufacture of lawns, while the town of Ypres, in Belgium, became noted for the manufacture of linen known as diaper—cloth de Ypres—and "holland" received its name through having been first manufactured by the Dutch settlers in Ireland. Napkins were introduced for wiping the hands, being all the more necessary owing to the lack of knives and forks at the time. For long periods these and other standard fabrics have been and probably will continue to be made, but the time has gone when the demand runs on one particular make or type of cloth to the exclusion of every other, which necessarily involves that the manufacturer who would succeed must learn to adapt himself to modern ideas and ever-changing fashions. No linen or other manufacturer can afford to stand still: to do so would be to drop out. In conclusion every manufacturing industry which is to obtain and maintain a position in the commercial world worthy of the name must seek to educate its workpeople by giving them a progressive course of instruction in the scientific and technical principles underlying their trade; for success now depends on scientific knowledge, research, and an intimate acquaintance with the inventions, the experiments, the successes and the failures of others: and whether our nation does or does not provide every facility in this direction, we may rest assured that textile production will continue its progressive course, and will be led by those who have made themselves capable of leading by adapted thought and knowledge, combined with enlightened energy, which directs its force to meet the vast and varied requirements of the world.

CHAPTER XVIII

RECENT DEVELOPMENTS AND THE FUTURE OF THE TEXTILE INDUSTRIES

ALTHOUGH nearly all the principles employed in textile machinery were in use, say, by 1850, still with what may be termed the refined organization of the twentieth century there have been, and apparently there will always be, opportunities for the improvement in so-called "details," which details are nevertheless so important that the status of the whole industry may depend upon them.

(1) **Buildings.**—Many improvements are to be noted in modern mill buildings when compared with similar buildings of, say, twenty-five years ago. With the materials best available—brick, stone or reinforced concrete—mills are now designed to give ideal conditions for working. The walls may be readily cleaned, and the floors are not only designed for cleanliness, but also to fatigue the workers as little as possible and to deaden noise. Roofs are so designed that, while perfectly stable, a maximum of light—other than direct sun-light—is obtained. The spans are so designed that few pillars are necessary, but a practically open space provided, into which the machinery may be planned at will. In storied buildings it is now possible to obtain such strength combined with light structure that the rooms may be considered as almost open to the light all round, and yet such a mill, four or five stories high, will carry with safety a roof-tank holding tons of water.

(2) **Power, etc., Equipment.**—The indirect advantages of electric driving are such that not only are almost all new mills electrically driven, but many old mills are being electrified. The question of "unit" or "group" driving is usually decided according to the particular machinery to be driven In some few smaller mills, suction gas plants are proving satisfactory. Almost without exception hot water or steam, for heating purposes or for use in certain processes, is a necessity. The suction gas plant will provide about 10 per cent. of the steam required for heating weaving sheds, but in electrically driven mills hot water or steam must be independently provided.

A good water supply is almost invariably required, and if the water is hard some softening system must be adopted. The Permutit process seems to dominate for this purpose.

Improvements in incandescent electric globes have been so marked that it would seem that electric lighting is more than holding its own. There is still usually room for improvement in the arrangement and distribution of light in most buildings intensity of light is only half the problem.

In England the atmosphere is correct for spinning during the major part of the year, but heat and moisture are so important that in both cotton and fine wool spinning it is found advantageous to control the atmosphere throughout the year. The introduction of ozone into the air is still under trial, but in many mills the controlled atmosphere is found by the workers to be actually refreshing and not to lead to enervation later. The vexed questions of temperature and moisture in dealing with certain materials are still matters of debate when the health of the operative, as well as the successful working of the material, is taken into account.

(3) **Details of Arrangement.** Material is being more and more automatically controlled. Thus, pneumatic conveyors may be arranged to carry wool efficiently for, say, 1,000 feet. Such conveyors should be so arranged that they may be thoroughly cleaned before changing from one blend (say black) to another blend (say white). For the conveyance of heavy articles—"workers" from the "card" for grinding, loom beams from the dressing-room to any loom, etc.—overhead rails are now almost invariably introduced.

(4) **Improvements in Special Machines.** Refinements in gilling, to take the place of the Continental intersecting gill-box, have been introduced by Messrs. Prince, Smith & Son, whose O.P.S. gill-box gives excellent control over short material. Automatic doffing machines for flyer and cap frames are still being evolved and, with the suppression of the "half-timer," will soon be well-nigh universal. In warping and dressing the warpers' beam system is ousting all other systems. In weaving no advances are to be noted, possibly owing to the fashion for plain fabrics. No special methods of designing have made good, but a revival of the figured trade might lead to further endeavours in this direction.

In finishing the Moser raising machine is now designed to raise or bind-in the pile developed.

(5) **Automatic Machines.** There has been a marked tendency to introduce automatic machinery in both the cotton and wool industries. Not only are automatic looms in evidence, but also automatic drawers-in, automatic tyers-in, and automatic lease-pickers are in daily use. Automatic machinery is often slowly run, and sometimes is run for hours without any attendants, thus economizing production.

(6) **Process Improvements.**—For special work certain

improvements are to be noted. For fine wool yarns the sorting room is now arranged for double sorting. Perhaps the most interesting development to be noted is the melanging of Botany tops to produce the finest possible wool mixture (melange) yarns. The Germans led in this in 1911, and unless other manufacturers follow this lead they will be left behind in efficiency of production there is no comparison between ordinary fibre mixtures and top-tinted "melange" styles from the point of view of "levelness."

(7) **Testing and Research.**—Most mills are now developing testing laboratories, and some of the largest factories private research laboratories also. Generally speaking, however, each section of an industry—the Fine Cotton Spinners, for example—is developing a federation research laboratory, or the whole industry—the woollen and worsted, for example is uniting for this purpose. Research will always find a place in the technical universities, especially when based upon the fundamental sciences, but there seems to be a useful field for such an association as the British Research Association for the Woollen and Worsted Industries, and also for the closely allied Cotton and Silk Research Associations. The cotton industry has also its Cotton Growing Association, which, it is hoped, will serve to promote the growing of cotton in the British colonies.

(8) **Scientific Management.** The more careful study of the worker along with his or her physical, moral, and æsthetical surroundings, is a feature in the developments of the past ten years to be specially noted. Machines are now more carefully adjusted to the workers; the activity of the work is so directed that the greatest production with the least exertion is ensured; and hours of labour are carefully considered. Welfare work is making much progress and, when offered in the right spirit

and accepted in the right spirit, tends materially towards efficiency in the broadest sense of the term. Industrial councils, established under the Whitley Act, are leading to the better psychological understanding of employees by the employers and, conversely, of the employers by the employees. Ultimately it may be possible to so raise the status of the mill workers that he or she may be regarded with envy rather than looked down upon as an outcast from society; and not the least indication of a move in this direction is the improvement in women's dress white shoes and stockings and well-cut, nicely coloured dresses are already in evidence in many factories, and are by no means to be condemned. Men so far are not showing such an advance in their attire and status as are women.

(9) **Industrial Economics.** The complexities prevailing in the industrial world have been much in evidence throughout the war and especially during the post-war period. To the outsider most of the principles of our economics seem to have been brought into question, but with the development of such an association as the Workers' Educational Association and the better education of the controllers of industry in our technical universities, it seems likely that the fundamentals of industrial efficiency and effectiveness may ultimately be more fully understood and acted on. A rise in wages was obviously long overdue, but the maintenance of anything approximating to the present level will by no means be an easy matter unless employer and employee alike realize that efficiency is the key to success. And this efficiency is now dependent upon something quite outside ordinary competition. From any given material nothing but the best result will serve; and to attain this, science and technology must be made the hand-

maidens of industry. France and Germany already know how to ensure this. The Anglo-Saxon, being more practical, has placed his faith in "driving force"; but he is learning better, and it may be that by his efficiently organized universities and technical colleges he may ultimately learn how to introduce "scientific method" into his activities without losing his "driving force." The future is to those peoples who consider their work worthy of careful thought and patient study.

INDEX